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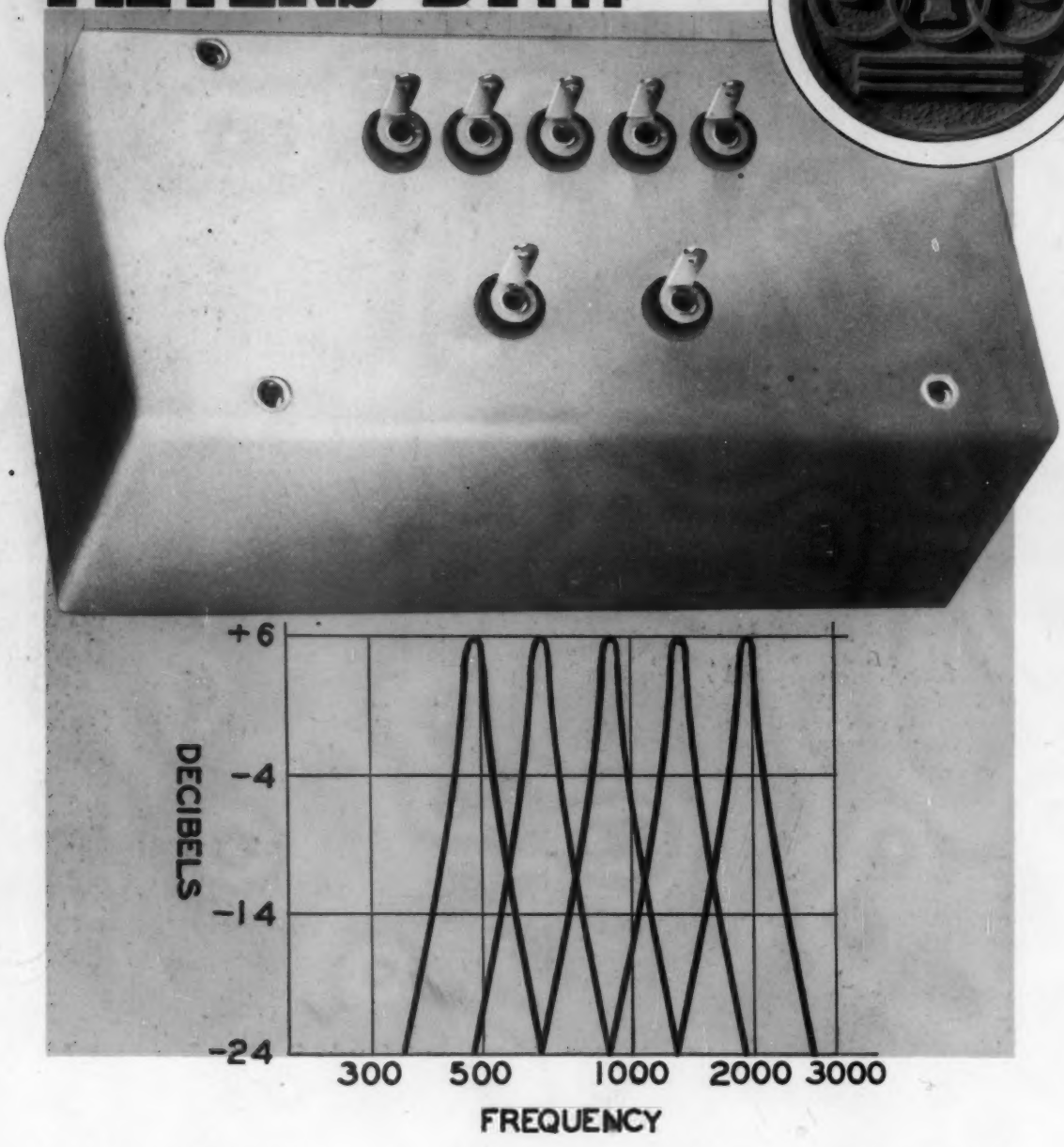
MULTI-CHANNEL FILTERS BY...



Multi-Channel Filters lend themselves to remote control apparatus employing frequency selection. The unit illustrated is a five channel band pass filter of the interstage type with the inputs in parallel and 5 separate output channels designed to feed into open grids. This circuit arrangement provides a 2:1 stepup ratio, with a band pass attenuation of approximately 30 DB per half octave. The dimensions of this unit in its hermetically sealed case are 2½" x 3" x 6". Filters of this type can be supplied for any group of band pass frequencies from 200 to 7000 cycles.

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The *Stake* of the United States in Expanding World Trade

WITH the war in Europe racing to a climax, and with a sure pattern for the defeat of Japan already outlined, American business is confronted with the need for an immediate decision on long-term economic policy.

What is this country's foreign trade program to be after the war?

No intelligent appraisal of all the factors any longer can allow us to postpone considering the issue merely because, in the past, foreign trade absorbed barely eight per cent of our production.

Actually, a whole new set of conditions was injected into the picture by the first World War; but we persisted in ignoring these new factors.

Almost overnight, the United States was transformed from the largest debtor nation in the world to the second largest creditor nation. At the same time, we made faster technological progress than any other nation. Thus we created the need for more dollar exchange on the part of the rest of the world and simultaneously made it harder for other nations to earn dollars.

Today, as another, far vaster war is approaching its end, those changed circumstances are magnified. America has new responsibilities—to itself, and to the world.

Our war-inflated industrial capacity cannot be allowed to drop back to prewar levels without causing a domestic crisis which we dare not permit.

And, because so much of the world is geared to the American industrial machine, we can no longer contemplate calmly the repercussions of a largely self-sufficient trade program or of an unplanned foreign trade program. Either would inevitably set the stage for the next world war.

☆ ☆ ☆

If we are going to prepare ourselves intelligently to cope with this new problem, we must acknowledge certain basic principles.

World trade cannot be rebuilt simply by attempting to restore *prewar* flows of goods. The war has so completely changed the economic fiber of many countries that it is necessary to develop *new* trade relationships. The East Indies, for example, may find the demand for their rubber considerably reduced; the United States may, to a large extent, have to cease exporting cotton; Japan will need to find new substitutes for much of its exports of silk; the British will need new markets to replace the income which they formerly derived from their large overseas investments.

We cannot expand markets for our goods, at home or abroad, unless we find ways of buying more supplies from more people at home or abroad, so that they will have more dollars to spend.

And we probably cannot create increasing buying power abroad without first exporting more of our technical skills—our engineers, our production and management men—to build new markets for our own specialties.

☆ ☆ ☆

What is needed to rebuild the world's economic system?

1. Most basic of all, of course, are stable governments which command popular support. In the absence of strong governments, currency stability cannot be achieved.

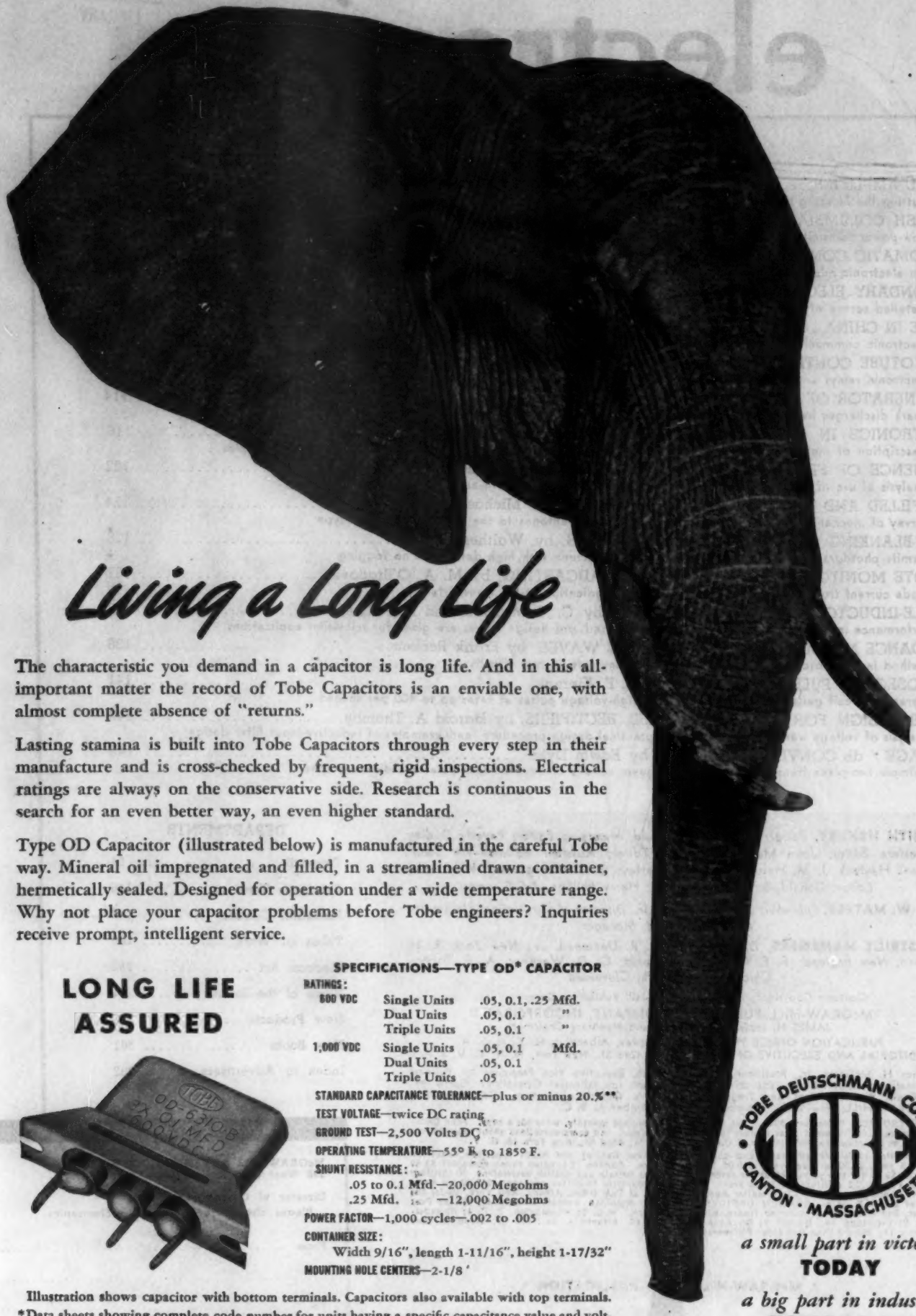
2. Most war-stricken countries, for a year or two, will need rehabilitation loans, because they will require far more raw materials, equipment, and live stock than they can pay for out of current production.

3. Loans, however, are only a stop-gap, though often a necessary one. Far more important than rehabilitation loans will be the creation of better opportunities for war-stricken countries to sell to the rest of the world, particularly to the United States, South America, South Africa, and India. The ravages of war do not completely destroy the ability of a country to sell. Indeed, it is surprising what large supplies of certain commodities war-torn countries have on hand even before devastated industries have been restored. The invading troops in Normandy found shoes almost non-existent, but they found food more plentiful than in Britain.

   Better opportunities for war-stricken countries to sell would create opportunities for them to buy the things they will require to restore scattered industries and depleted farms, and would help those countries to get rid of the exchange controls which are now universal. So long as a country is able to expand its exports only slowly and painfully, and is dependent upon foreign loans to prevent the depreciation of its currency, so long will it carefully preserve exchange controls and other restrictions in imports. That is why large advances, either through an International Monetary Fund or an International Investment Bank, can make only limited contribution to the removal of trade restrictions.

4. Permanent monetary and credit arrangements are needed to protect nations against temporary pressure upon their currencies, to permit necessary changes in exchange rates to be made in an orderly manner, and to assure that governments never again will repeat the "beggar-my-neighbor" policies of 1931 and 1932.

5. Finally, the world needs a reversal of the trend toward economic self-sufficiency, which received a strong impetus from the first World War and an even stronger one from the great depression of the Thirties. This does not mean that the efforts of many raw-material producing countries to diversify their industries should be opposed. During the late Nineteenth Century and the first part of



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Type OD Capacitor (illustrated below) is manufactured in the careful Tobe way. Mineral oil impregnated and filled, in a streamlined drawn container, hermetically sealed. Designed for operation under a wide temperature range. Why not place your capacitor problems before Tobe engineers? Inquiries receive prompt, intelligent service.

LONG LIFE ASSURED

SPECIFICATIONS—TYPE OD* CAPACITOR

RATINGS:

600 VDC	Single Units	.05, 0.1, .25 Mfd.
	Dual Units	.05, 0.1 "
	Triple Units	.05, 0.1 "
1,000 VDC	Single Units	.05, 0.1 Mfd.
	Dual Units	.05, 0.1
	Triple Units	.05

STANDARD CAPACITANCE TOLERANCE—plus or minus 20.%**

TEST VOLTAGE—twice DC rating

GROUND TEST—2,500 Volts DC

OPERATING TEMPERATURE—55° F. to 185° F.

SHUNT RESISTANCE:
.05 to 0.1 Mfd.—20,000 Megohms
.25 Mfd. —12,000 Megohms

POWER FACTOR—1,000 cycles—.002 to .005

CONTAINER SIZE:
Width 9/16", length 1-11/16", height 1-17/32"

MOUNTING HOLE CENTERS—2-1/8"

Illustration shows capacitor with bottom terminals. Capacitors also available with top terminals.
*Data sheets showing complete code number for units having a specific capacitance value and voltage ratings available on request. **Other tolerances available.

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TODAY
a big part in industry
TOMORROW

this century, the international specialization of production was carried too far, with the result that many countries became dependent for a large part of their standard of living upon the export of one or two raw materials—coffee, sugar, rubber, silk, wheat, wool, and meat. Between the two World Wars, however, the pendulum swung much too far in the direction of self-sufficiency. Some densely populated industrial countries of Europe (Italy, France, and Germany) even attempted to become self-sufficient in wheat, fats, and sugar. So limited are the natural resources and technical skills of most countries that each one finds many things which it can produce only at prohibitive costs. Between the extreme specialization of the late Nineteenth Century and the more recent trend toward extreme self-sufficiency, a happy medium should be sought.

☆ ☆ ☆

What role should the United States play in reconstructing the world's international economic system?

There are those who suggest that the United States be a more or less permanent Santa Claus. They believe that an excess of exports could be financed only by "loans"—loans that would eventually turn into gifts, after producing bitter controversy over why the "debtor" country did not meet its obligations. The persons who assert that full employment can be provided only by an excess of exports are in effect saying that our economy cannot become self-supporting. That is a confession of economic defeatism which a young and vigorous nation should not be willing to make.

The most immediate contribution which the United States can make to world reconstruction is to make itself prosperous.

Prosperity here means a large demand by our industries for imports. The more we import, the easier will it be for foreign countries to meet their large and urgent needs for goods. In 1939, with a gross national product of $100 billion, our imports were $3 billion. After the war, with 55 million people employed and a gross national product of $155 billion, our imports would be about $7 billion or $8 billion.

Not only should the United States make itself prosperous, but it should *keep* itself prosperous. *So important is the United States in the world economy that a depression here is bound to produce a disastrous drop in the price of raw materials throughout the world and to throw most countries into an economic tailspin.*

The United States should support the principle of a large fund to protect the exchanges of the world from temporary pressure. We should not permit differences over the details to prevent its establishment in ample time to be available during the critical period when war-stricken countries will need goods far in excess of their immediate ability to pay for them. *Some* arrangement, even though imperfect in details, will be infinitely superior to no arrangement.

Finally, the United States should take the lead in breaking down barriers to trade. We are the logical country to do this, partly because of our immense domestic market, and partly because for most of the last twenty-five years this country has been able to sell other countries more goods than they have been able to sell to us. One of the greatest contributions which the United States could make to a sound and expanding world economy would be to bring our imports, as soon as practicable, up to our exports. *In other words, the United States, in the long run, should be hard to borrow from but easy to sell to.* The United States should implement this policy (1) by continuing the negotiation of reciprocal reductions in duty, and (2) by accepting exchange rates which make foreign currencies cheaper in dollars than they were in 1939. So great will be the world's need for goods that we can be sure that any dollar exchange earned by sales to us will be converted into American-made goods and will lead to larger exports.

Time was when the United States obtained about eight per cent of its standard of living by sending goods abroad and bringing back other goods. Before the war, however, we were getting less than five per cent of our living by international trade. If, after the war, we were gradually to raise the proportion of our standard of living obtained by trading with other countries to ten per cent of domestic production, our imports would be about $15 billion or $16 billion a year. Our people would be able to buy many things which they now cannot afford, and scores of countries which export raw materials and luxury products would feel the stimulus of rapidly expanding markets. Their expanded demand for road building machinery, mining machinery, machine tools, agricultural implements, locomotives, railroad cars, electrical equipment, trucks, automobiles, and a multitude of products of our factories would create a million or more additional jobs in our factories.

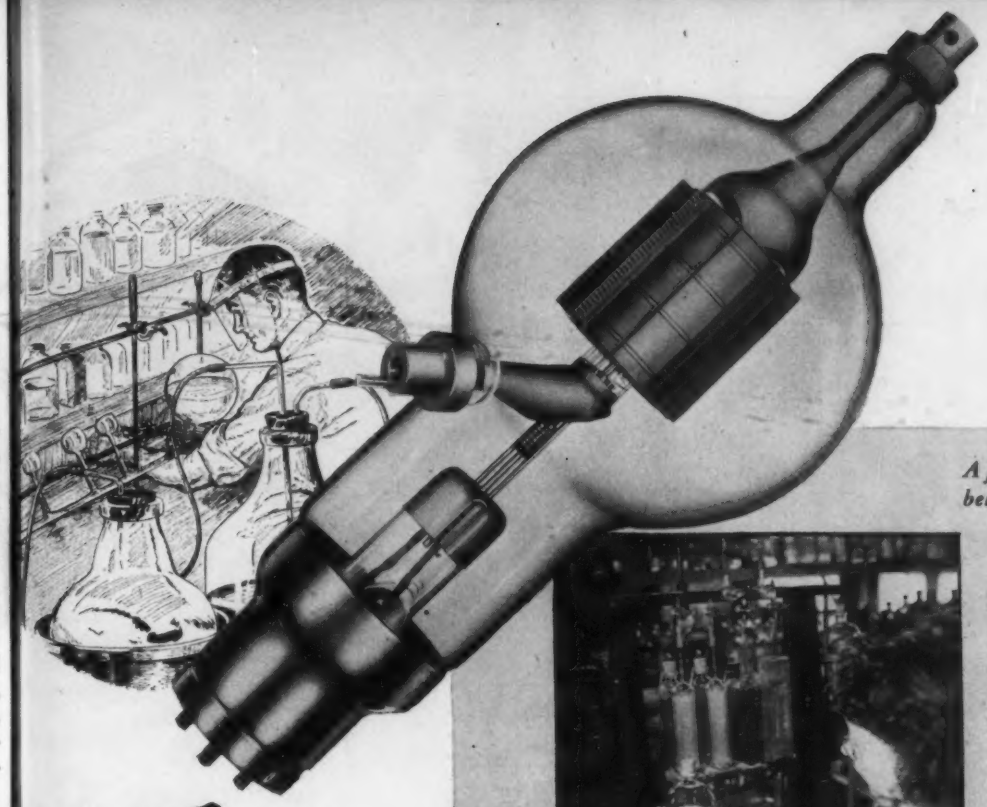
Although the United States would raise its standard of living by increasing its imports and its exports, it should honestly face the fact that the resulting shifts in production and employment would temporarily be painful for some people. The increase in imports would be in commodities which other countries can produce for less than the cost at which much of our output is produced—such as sugar, wool, copper, some fats and oils, wines, winter vegetables and fruits. The increase in our exports would come from those industries in which our superiority is greatest—particularly the manufacturing industries. Finally it would be advantageous, to the country as a whole, to shift a million or two workers from agriculture, where they earn about 60 cents an hour at best, to manufacturing, where they earn better than 80 cents an hour.

☆ ☆ ☆

The very fact that in economic matters the rest of the world is dependent upon the United States, exposes our country to great demands and to envy and misunderstanding. The United States must be willing to help the rest of the world, but its help should take the form of assisting other countries to help themselves. Never in all history has one country had such an opportunity to give the world a rising standard of living, to foster conditions under which peace flourishes. What greater tragedy could there be than to make the sacrifices which we are now making and fail to seize this chance to create a world of hope and opportunity in which the spirit of goodwill among nations is able to flourish.

James H. McGraw, Jr.

President McGraw-Hill Publishing Company, Inc.



the *Science* behind the science of electronics

The pattern of progress in the science of electronics is determined by the achievements in creating and developing new and more efficient electron vacuum tubes. Therefore, the whole complex task of vacuum tube development — involving the intelligent application of many sciences — comprises the real science behind the science of electronics.

To create and produce the modern vacuum tube requires experience and skill of the highest order in these many sciences in addition to complete facilities for their application. The list includes everything from chemistry and metallurgy — the technology of glass fabrication and vacuum pumping — to physics, optics, thermo-dynamics and most important of all — electronics.

The resources and resourcefulness of Eimac laboratories have accounted for many outstanding contributions to the science of Electronics. A fact which is attested to by the leadership which Eimac tubes enjoy throughout the world. These comprehensive facilities are continuously being utilized to achieve better and better results for the users of Eimac tubes.

Eimac Engineering is devoted solely to the development and production of electron vacuum tubes. However, since the electron vacuum tube is the heart of all electronic devices it is advisable for users and prospective users of electronics to look first to the vacuum tubes required. A note outlining your problem will bring advice and assistance without cost or obligation.

• • •

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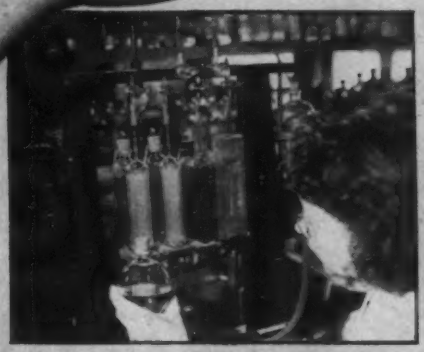
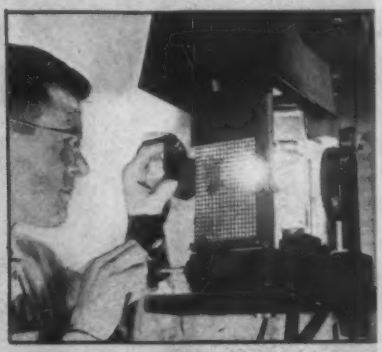
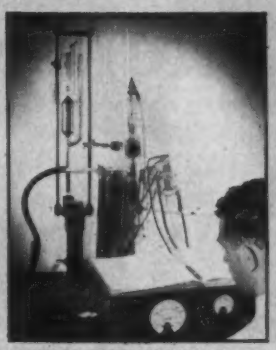
A few of the branches of the Science behind the Science of Electronics



CHEMISTRY—*Making Gas Analysis in the Eimac Laboratory*



METALLURGY—*Spectrographic Analysis of the Rare Metals Used in Vacuum Tubes*



VACUUM TECHNOLOGY—*Constant Research to Develop Better Vacuum Techniques*

PHYSICS—*Actually Viewing Emission of Electrons with Electron Microscope*

ELECTRONICS—*Determining Facts about and Recording Data on Vacuum Tube Capabilities*

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Mallory Dial Lights — In screw base and bayonet base types.

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The switch is available in two different types: a non-locking model which operates only when the button is pushed in and releases on removal of pressure . . . and a locking switch which maintains its position when the button is pushed in, and is released only when the button is pulled out. In either case, eight circuit combinations are provided, and the switches can be mounted on panels up to ¼ inch thick with a single hole 7/16 inch in diameter.

For other precision electronic parts geared to today's specifications and backed by Mallory's wide application knowledge, send for the Mallory Catalog or see your Mallory distributor. A few typical Mallory products are mentioned at the left.

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CROSS TALK

"An alert Navy must have appropriations from Congress for extensive research in time of peace. Research before a war is the only research which will do us any good on the day the enemy strikes."

James Forrestal, Secretary of the Navy, *Saturday Evening Post*, June 24, 1944.

▸**RESEARCH** . . . It is an unfortunate fact that a very great deal of the research which is now bearing us such good fruit in the war was started almost too late. In some branches of the armed services, forward-looking research had practically ceased, either due to lack of foresight or imagination, or due to the fact that Congress would not provide the funds for it. After every war, the people lull themselves to sleep with the happy hopes that no further war-like expenditures will be necessary, and, therefore, no more taxes need be collected for preparation for future conflicts.

Admiral Mahan, in his well known treatises on naval history, cites chapter and verse to show that after every war in which this country is engaged there arises a clamor to stop all warlike activities, to get back to "normal" and to stop spending money so that the people can make more of it.

As soon as peace seems close, watch for an outcry to lower taxes, to stop the expense of further research. Watch for all of the age-old arguments which a people, tired of war, eternally advance for going back to sleep. Remember that savings made by stopping research are only illusory; that money saved before a war is spent many fold after a war starts; that abundant research prior to a war may prevent it entirely.

▸**STANDARDIZATION** . . . Some people make a fetish of the business of standardization. Certainly the subject can be worked so hard that the potential benefits are not secured. Yet the recent happy conclusion of the conflict in the symbols used for electronic components leads one to hope that additional benefits could be secured by some standardization of the components themselves.

The vast number of different types of electronic components is a great waste of manufacturing effort, a waste of storage space, a great burden on radio service agencies and a great trouble to manufacturers and users of radio sets.

Most of the different types of components vary from each other in minor degree only; a very great many of them could be eliminated. It is true that the designer who uses the components would have fewer types to choose from—but it is a fair assumption that he, too, would find his problems simplified, not magnified, by standardization of this kind.

Broadcast Relay System

Remote valleys in rugged western Canada are difficult to serve by conventional broadcast methods. The problem is solved by installing 25-watt transmitters in local telegraph and telephone offices through which network audio flows and feeding part of the r-f output of these transmitters back into the wire lines, which serve as carrier conductors

mitter was connected to the common equipment ground. The antenna consisted of an inverted L with a flat top 120 ft long, running slightly above and approximately parallel with the telegraph lines.

During field-test periods power output was maintained at 16.2 watts. Peak program modulation was held at 60 percent except during station breaks, at which times the transmitter was switched to icw and the output raised to 20 watts. Even during the latter periods local and distant repeater operators were unable to detect any trace of interference on telephone, telegraph or carrier-telegraph channels.

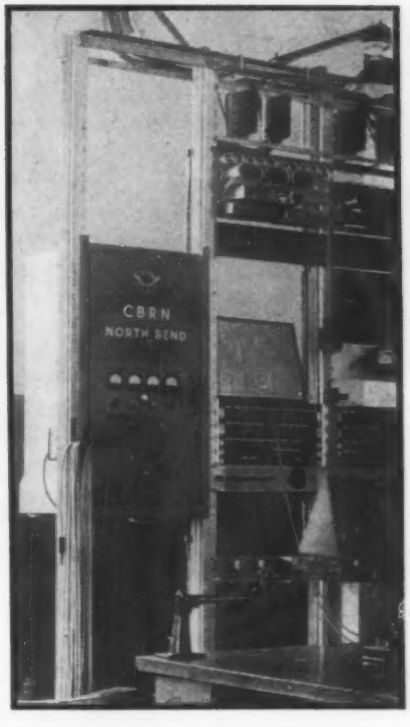
It was not possible to make many field-strength measurements at the time, but readings on signals radiated directly by the antenna and not aided by telegraph line carrier characteristics indicated approximately 100 microvolts-per-meter at points five miles away from the transmitter. On the other hand, due to the carrying effect of the telegraph circuits, the signal at points up to 500 feet from these circuits and 15 miles from the transmitter gave readings of 300 microvolts-per-meter or more. The signal radiated by the telegraph lines, which could be followed up and down the right-of-way for approximately 40 miles, transferred to local circuits at Yale and Lytton, providing a useable signal even at these points although both are well outside the normal ground-wave service area.

Practical Application

The financial failure and closure of the privately owned station in Revelstoke, in the late fall of 1940, and subsequent requests from listeners in that area for continued

FIG. 2—(above) Relief map of British Columbia. Circles indicate the location of low-power relay stations radiating a portion of their r-f output into telephone, telegraph and power lines as discussed in this article. Triangles show other stations of the CBC and squares identify private commercial stations associated with the network. 1—CBR-CBRX, Vancouver; 2—CFPR, Prince Rupert; 3—CBRG, Prince George; 4—CBRQ, Quesnel; 5—CBRL, Williams Lake; 6—CBRN, North Bend; 7—CBRA, Revelstoke; 8—CBRM, Creston; 9—CBRK, Kimberley; 10—CBRR, Cranbrook; 11—CBRF, Fernie; 12—CJVI, Victoria; 13—CJOR-CKWX, Vancouver; 14—CHWK, Chilliwack; 15—CFJC, Kamloops; 16—CKOV, Kelowna; 17—CJAT, Trail; 18—CKLN, Nelson

FIG. 3—(below) The experimental low-power relay station, installed in a telegraph repeater office at North Bend. It is now in permanent use



British Columbia's B

By N. R. OLDING
Regional Engineer
Canadian Broadcasting Corp.
Vancouver, B. C.

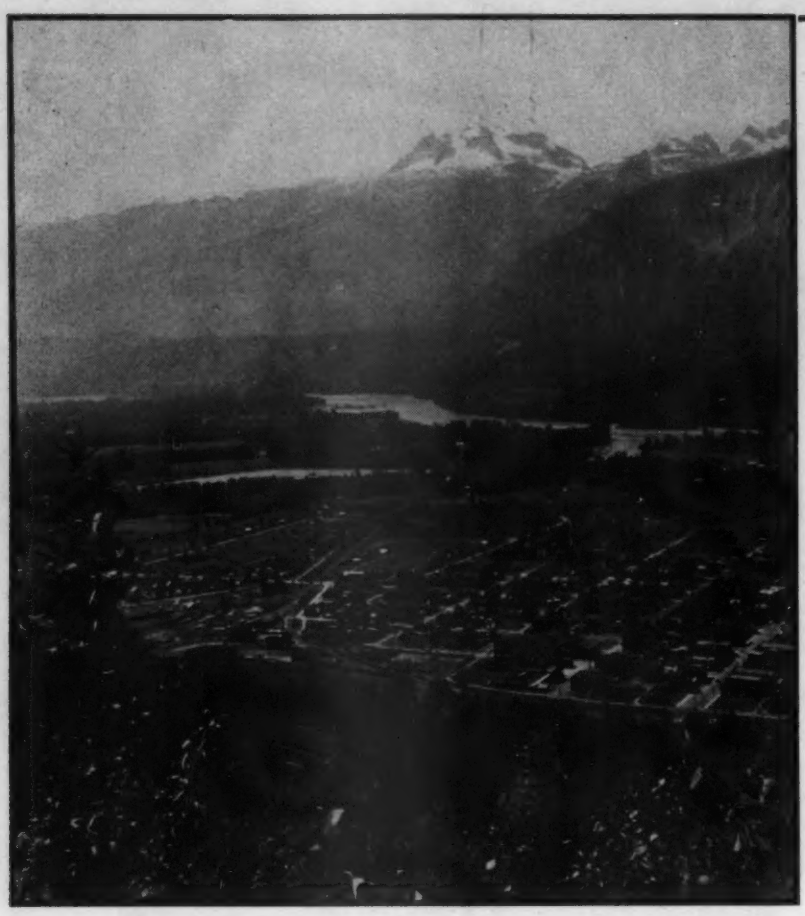


FIG. 1—Revelstoke, B. C., showing the nature of the terrain which renders broadcast service difficult in this Canadian province

THE MOUNTAINS which have made British Columbia so attractive to the tourist and so rich in minerals, present many difficult problems to engineers. Among these is the very real problem of providing satisfactory radio reception for scattered groups of listeners residing in remote valleys among several mountain ranges which divide the province. To the extremely rapid attenuation of the ground wave associated with rocky terrain must be added the adverse effects of radio shadows and reflections from high mountains such as those pictured in Fig. 1 and 2.

Due to these conditions, it soon became evident that adequate coverage could not be provided with one or two high-powered transmitters, regardless of how strategically these might be located. While the use of shortwave transmitters offered a partial solution, the wide angle of transmission required and the distances involved were deciding factors in limiting this means of transmission to auxiliary service. The method finally adopted utilizes numerous low-power transmitters operating on standard broadcast channels. Some of the power from these transmitters is fed into existing wire lines serving the remote valleys and this is the most important feature of the system.

Initial Test Results

Everyone who has made field-strength measurements knows that telephone, telegraph and power circuits act as carrying conductors for radio waves. With this in mind, a test unit was set up with the following objects in view:

(1) To determine the minimum power required to serve a community of from 500 to 5000 population.

(2) To determine the improvement in coverage obtainable by utilizing the carrying effect of nearby copper circuits.

(3) To determine whether or not it would be possible to feed limited power into local copper circuits without creating interference on telephone and carrier-telegraph circuits.

North Bend, a small railway town on the banks of the Fraser River at a point known as the "Gateway to the Cariboo", was chosen as a test site. In view of the nature of the tests to be conducted, the site had much to recommend it. The town is on a narrow ledge between a mountain and the river and on the other side of the river a similar condition prevails. The nearest center of population to the south is at Yale, about twenty-three miles airline, and the nearest center of population to the north is at Lytton, twenty-five miles airline. (A Canadian Pacific Communications repeater station, carrying CBC network service, is located in North Bend and the strongest daytime signal on the broadcast band was somewhat less than 1.0 microvolt-per-meter.)

A Marconi TR50P shortwave transmitter, converted for use on 840 kc and operated under experimental license VE9BC, was installed in the local telegraph repeater station as shown in Fig. 3. The ground lead from the trans-

radio manufacturer, Vancouver Radio Laboratories, Ltd., on the design of suitable units. (A number of equipment photos included here were supplied by the Laboratories.) This arrangement proved very satisfactory as the local plant already had considerable experience in the construction of transmitting units to be used in remote districts where long life with a minimum of service were essential factors. The resulting design is shown schematically in Fig. 4.

Requirements 1 and 2 were met by the use of two 807's or RK39's operated in parallel with 390 volts on the plates, as the modulated r-f amplifier, and two similar tubes, operating with 400 volts on the plates, as class-B modulators.

Requirement 3 was met by the use of inductive tuning in the antenna tuning unit and by the use of a three-turn lightning choke, with horn gap to ground on the antenna side of the choke. This choke is installed outside, at the point where the lead-in bus enters the building. A typical antenna installation is shown in Fig. 5.

Requirement 4 was met by the use of a Thordarson 350-watt voltage-regulating transformer between the local power outlet and the 110 volt a-c input to the transmitter.

Items 5 and 6 were met by the use of four meters. Instead of reading antenna current directly, a 0 to 1 ma d-c milliameter reading rectified carrier is used to indicate normal antenna current and at the same time provide a means of maintaining proper current for the operation of the percentage-modulation indicating meter. A 0 db at six milliwatt volume-indicating meter provides both input audio and percentage modulation readings. The rather novel circuit used is discussed more fully later. Final amplifier plate voltage and current meters provide the other essential readings.

Item 7 was incorporated with the input and output V. I. meter circuit.

Item 8 was met by the use of meter jacks and screwdriver-operated controls which are normally concealed and protected by a dress panel.

Item 10 was met by the use of a 0.001 fixed-mica tank capacitor in the modulated amplifier stage and loose link-coupling between the final amplifier tank coil and the antenna tuning unit.

Items 11 and 12 were met by the use of high-quality audio components and by the addition of a single stage of audio amplification before the class-B driver stage.

Transmitter Design Details

The transmitters are made up of three units, as pictured in Fig. 6. The top section contains the speech amplifier, modulator, crystal oscillator, buffer and modulated r-f amplifier, shown in greater detail in Fig. 7. The oscillator and buffer tank coils are mounted in a shield can on top of this chassis, while the final amplifier tank coil and the antenna loading coil are mounted on the inside of the top of the cabinet.

Referring again to Fig. 4, the r-f section of the transmitter consists of a 6V6 crystal oscillator very loosely coupled to a 6V6 operating as a high-mu triode buffer. The buffer is capacitance-coupled to two 807's or RK39's connected in parallel and operating as a class-C modulated amplifier. A 0.001-μf fixed-mica capacitor is connected across the final amplifier tank coil and the circuit is tuned to resonance by means of taps and a rotor in the L_1 coil form.

The antenna circuit is resonated by means of a tapped inductance and a rotor in the L_2 coil form. The tank circuit and the antenna circuit are coupled by means of a link which has fixed coupling at the tank coil end and an adjustable sliding coupling at the antenna tuning coil end.

The oscillator and buffer plate circuits are tuned by means of variable capacitors. The tuning knobs are mounted on the front of the top chassis but are normally concealed by the dress panel. Four jacks are provided on the top chassis for test-metering the oscillator plate, buffer grid, buffer plate and final amplifier grid circuits.

The speech equipment consists of a 6C5 audio amplifier, 6C5 driver and two 807's or RK39's in push-pull as modulators. The input transformer is 10,000 ohms bridging, and the balanced primary terminal and center-tap leads are brought out to the rear.

The center unit contains a 6H6 carrier rectifier and 6V6 amplifier. Four meters are mounted on the

FIG. 5—The telegraph station at North Bend, in which the broadcast relay transmitter using the call-letters CBRN is installed. The tall white pole just to the left of the building supports one end of the antenna, which runs immediately above and parallel to the telegraph wires which appear beneath

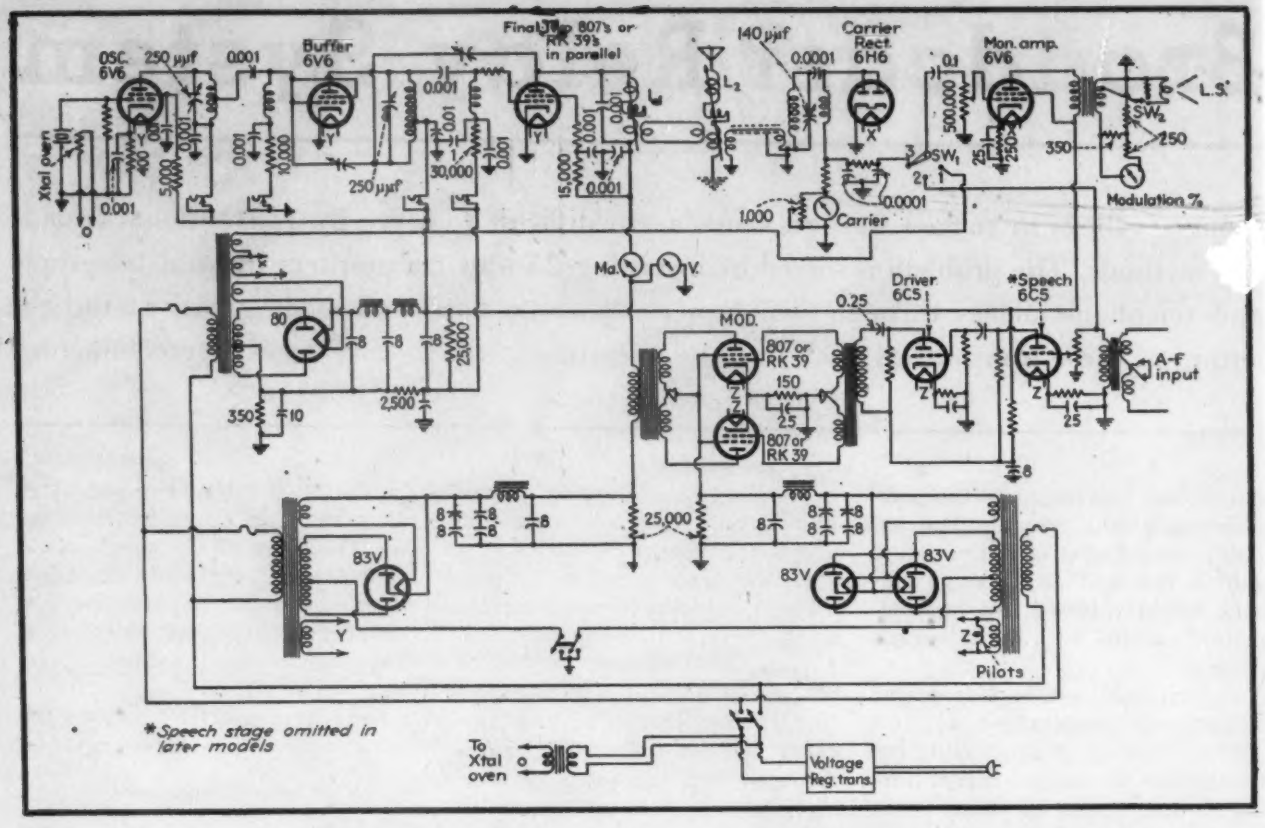


FIG. 4—Schematic of the low-power relay transmitter finally developed for use at a number of locations in British Columbia. The r-f portion of the unit may be seen at the upper left; the associated monitor and its amplifier appear at the upper right, with the modulator and speech amplifier diagramed below the monitor. Other circuits are power supplies

service, presented an immediate opportunity for the CBC Engineering Division to put the foregoing experience to practical test.

On October 22nd, 1940, the first "Low-Power Relay Transmitter", operating under the call CBRA, was installed and placed in operation on a sixteen-hour-a-day schedule. In the beginning the converted Marconi unit, with some further refinements such as temperature control of the crystal oscillator, was used. Although this transmitter was designed for intermittent service it stood up well. However, because many other points were demanding improved service, the development of a special transmitter unit which would work into various antennas and on erratic local power supplies was undertaken.

The requirements were as follows:

(1) The power output should be between 20 and 25 watts.

(2) The tube line-up should be as simple and efficient as possible.

(3) The antenna-tuning unit should be relatively free from failure due to static or lightning.

(4) The unit should give long and reliable service on fluctuating or poorly regulated power supply.

(5) A minimum of meters consistent with reliable operation should be used.

(6) Meters should be provided to measure the audio input level, antenna current, percentage modulation, final amplifier plate voltage and final amplifier plate current.

(7) The unit should incorporate a monitor, with provisions to switch the input to either the audio line or the rectified r-f carrier.

(8) As the unit would in many cases be operated by relatively inexperienced personnel, a minimum of adjustable controls should appear on the exposed panel and the operation should be limited to throwing switches on and off and reading the meters.

(9) As an aid to servicing, it was proposed to fuse each major circuit separately and to construct the unit so that individual chassis units could be readily removed when required.

(10) The antenna coupling unit and final amplifier tank should be designed to permit efficient coupling with a minimum of harmonic radiation.

(11) Frequency response should be equal to, or better than, that of the network, or ± 2 db from 100 to 5000 cycles.

(12) The audio input should be arranged for bridging across a 600-ohm line and the input amplifier should have sufficient gain to permit 100 percent modulation peaks to be attained on line levels as low as — 10 to — 20 db.

(13) Last, but most important, all components should be operated well below their rated capacity.

As no equipment meeting all these requirements was available on the market, arrangements were made to cooperate with a local

sists of bringing the antenna, ground, audio and power leads to the transmitter unit and connecting them to the proper terminals. When this has been done the equipment is turned on and the antenna circuit is tuned to resonance. The output is then adjusted by means of the variable-link coupling and, when properly adjusted, tone from an audio oscillator is fed to the input at the normal peak program level at that point and the balance of the adjustments are made so that all meters read correctly. During the installation a cathode-ray oscilloscope and standard impedance and distortion-measuring sets are used to assure normal operation.

The operators, who are usually members of the telegraph repeater staff, are instructed in the general operation of the equipment and are shown how to detect defective tubes and replace fuses. They are required to check the transmitter at least four times a day and enter all readings on a log sheet which is provided. For the first few weeks these logs sheets are forwarded to the CBC regional engineer's office once a week, but if the unit operates normally during the trial period the operators are requested to submit log sheets every two weeks. On receipt of these logs the average readings for each 10th day of operation are entered on a special sheet and in this way there is a permanent record which shows the gradual failure of tubes, etc. If no abnormal readings or actual off-air periods are noted the units are checked three to four times a year. The checking is very thorough and is similar in most respects to the check made during the original installation.

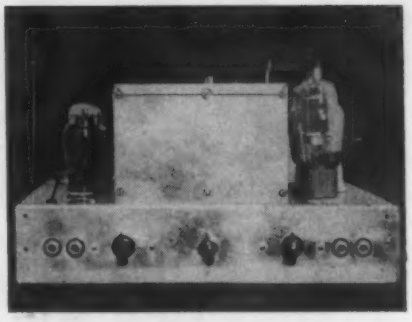
In order to avoid long rush-trips to service a single unit which has failed in service, arrangements have been made with a selected radio serviceman in each locality to handle emergency calls. This man is supplied with a maintenance manual and up-to-date service data sheets. The men selected for this work are ex-amateurs, commercial radiophone and code operators, qualified radio servicemen or motion picture projectionists. Except for emergency and temporary repairs all parts are supplied by the CBC and spare tubes, fuses, etc., form a part of each installation. This method of emergency servicing has proved quite satisfactory in the few cases where it has been required.

Another installation of particular interest is that at North Bend, where local 110-volt a-c power is not available during the day. At this point the transmitter operates, for a part of the broadcast period, on one of the 130-volt repeater storage batteries. The voltage is dropped to 115 volts by means of a series resistor and is converted to 115 volts a-c by means of a type 233 Electronic Labs., Inc. vibrator-converter. As the frequency of the local power is fairly constant and as the battery-charging time-cycle is short, the voltage-regulating transformer was eliminated at this point. When operating on batteries the direct current drain varies from 3.1 (start) to 2.8 (finish) amperes. The normal a-c input to other units averages 248 watts, but the addition of the voltage-regulating transformer naturally increases the input slightly.

Program Pickup Facilities

As these units were designed for operation in the smaller communities and as no associated local studio facilities have been provided, the standard practice is to bridge the transmitter audio input across the CBC's Trans-Canada program circuit. At the termination of a branch network circuit, or where the transmitter is fed from a separate amplifier, a 500-ohm non-inductive resistor is connected across the audio input terminals of the transmitter or this resistor and a 500-0-500 pad having the required loss is used to terminate the circuit. In all cases a 1:1 isolating transformer is connected between the network feed and the audio input to the transmitter. The use of this transformer, together with a separate ground for the r-f output of the transmitter, effectively prevents stray r-f fields.

Connected in this manner, these network satellite transmitters carry all programs on the CBC's Trans-Canada network in the Province in which they are located. Call letters are assigned by the addition of a letter to the call letters of the predominant station in the Province.



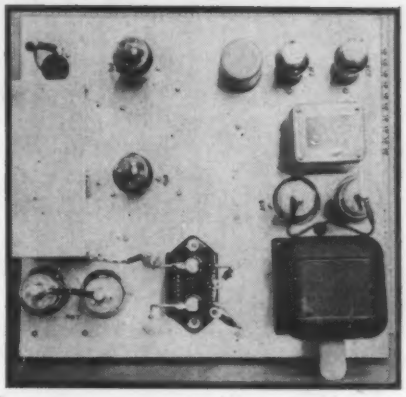


FIG. 7—Front and top views of the r-f and a-f chassis forming the top deck of the CBC low-power broadcast relay transmitter

In British Columbia the predominant station is CBR, hence the network satellite transmitters are assigned calls CBRA, CBRG, etc.

Improvements in Future Units

It requires long periods of service to show where improvements can be made and in the case of existing and new units the following conversions will be made:

(a) Oil-type filter capacitors will be installed to replace all high-voltage electrolytic units.

(b) All toggle switches will be replaced by switches which will handle considerably heavier loads. (The primary power switch sometimes fails in service although operated within the rated load. The contact resistance of the loudspeaker off-on switch increases with use until it becomes appreciable in relation to the relatively low impedance of the voice coil or resistive load).

(c) The loudspeaker unit will be fitted with a volume control.

(d) The first audio amplifier stage will be deleted, as the amplification provided by this stage is not normally required.

In addition to these changes,

(*Continued on page* 304)

control panel: carrier meter, volume indicator, milliammeter and voltmeter. The latter two are used to read the input to the final amplifier. Also on this panel are mounted the coarse and fine controls used to set the carrier meter to read mid-scale, the filament "off-on" switch, the plate voltage "off-on" switch, a meter switch and the 6V6 amplifier gain control.

The meter switch SW_1 permits the V. I. meter to be connected to (1) the calibrating voltage, (2) the input from the audio network or (3) to read percentage modulation. With loudspeaker switch SW_2 "on", the meter switch also permits oral monitoring either off the network or off the air.

When the meter switch is in "calibrate" position the V. I. meter-amplifier is connected across a fixed a-c calibrating voltage which, due to the fact that a primary voltage-regulating transformer is used, is reasonably constant. This reading will indicate whether or not there has been any change in the original adjustment or gain of the amplifier. If the V. I. reads other than zero in the calibrate position the amplifier gain control is reset so that the meter reads 0 db. When these readings and adjustments are being made the loudspeaker switch must be in the "off" position. This substitutes a resistive load in place of the voice coil. With the switch set in the "modulation" position and the transmitter turned on and modulated 100 percent at 1000 cycles, the coupling of the sampling coil in the antenna tuning inductance is varied until the V. I. meter reads 0 db (100 percent modulation). The coarse and fine carrier-meter adjustments are then set so that the carrier meter reads 0.5 ma (mid-scale). Thereafter, if the V. I. reads 0 db when the meter switch is set on the calibrate position, the meter will indicate the approximate input level in db when the switch is set to "Input" and will indicate 100 percent modulation when the switch is set in the "modulation" position and the meter reads "0 db".

Three separate power supplies are mounted on the bottom unit. One power unit supplies the heaters on the middle unit and B voltages to the crystal oscillator, buffer and monitor amplifier. The second power unit furnishes the heater power for all of the r-f tubes and B voltage for the class-C amplifier. The third power unit supplies the heaters of the audio tubes and furnishes the B voltage for the modulator tubes.

A separate transformer, which remains energized at all times, supplies the power for the crystal heating unit.

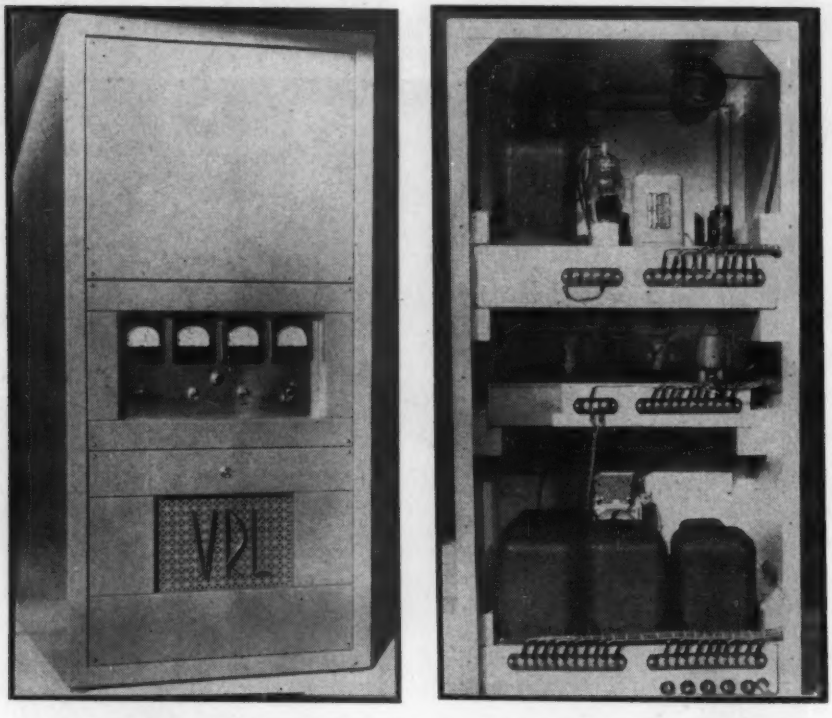


FIG. 6—Front and back views of the transmitter design finally adopted. Because these transmitters are operated by men in telegraph offices and others relatively unfamiliar with such equipment, controls to which they have access are limited. Other adjustments, and meter jacks for use by servicemen and CBC engineers, are concealed behind dress strips on the front panel

Typical Installations

The first of the new units was installed in Revelstoke in July, 1942, as noted in an earlier paragraph. This was followed by installations at North Bend in September, 1942, in the East Kootenay area at Fernie, Cranbrook, Kimberley and Creston in December, 1942, and in the Cariboo area at Williams Lake, Quesnel and Prince George in August, 1943. In addition to the units installed in B. C., three units have been shipped to eastern Canada and are now in service in Sioux Lookout and Nakina, Ontario, and in Edmunston, New Brunswick.

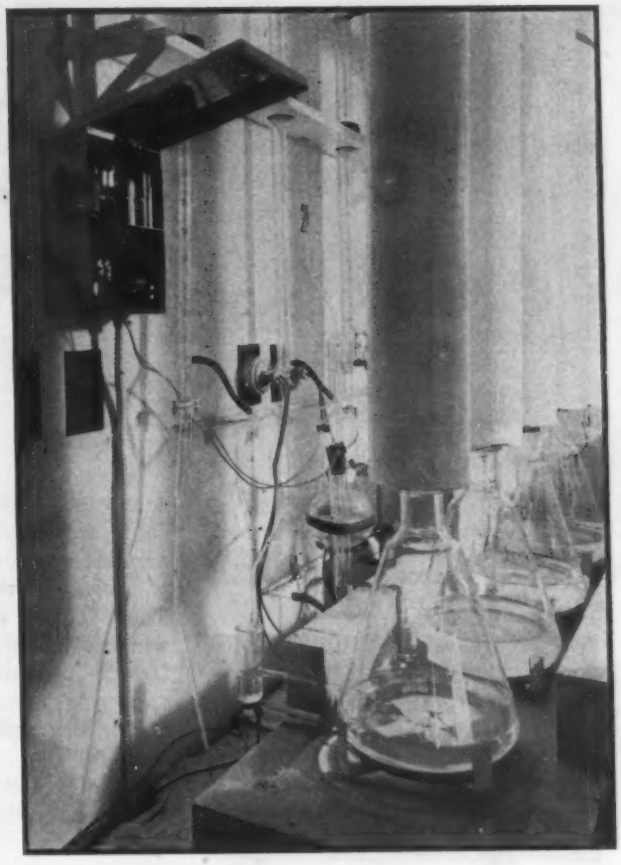
Station CBRF, operating on 940 kc at Fernie, is installed in the Canadian Pacific Railway's communication office in the Fernie railway station. The antenna is an inverted L running NE and SW, parallel with the telegraph lines and railway tracks. The flat top is 112 ft long and 50 ft high. The lead-in runs NW from the SW end of the antenna and is 78 ft long. The ground system is buried in and around the station garden plot. It consists of 500 ft of No. 10 bare copper wire buried under the antenna in the form of three parallel wires cross-connected at the center and at both ends. Each of these wires is securely fastened and soldered to the transmitter ground lead, which is a No. 6 rubber-covered flexible stranded copper cable. The lightning ground lead consists of a similar cable connected to a six-foot ground rod.

As no equipment rack space is available at this point the transmitter is installed on a small table designed to accommodate the transmitter and the voltage-regulating transformer.

As all transmitters are tuned to frequency and neutralized before shipping, the field installation con-

CONTROL

Current flowing through water between two electrodes sealed in the system operates an electronic relay. The relay operates an electromagnetic valve in the feed line and a switch through which power is delivered to the boiling-flask heaters



Electrically heated stills designed for laboratory use, with insulating brick removed to show the flasks. The electronic control unit may be seen on the wall at the upper left

current is flowing through the solenoid the weight of the core and stem is sufficient to close the valve.

An attempt to use a glass float and mechanically operated level control proved unsatisfactory. This method was unreliable and made it difficult to provide suitable sealing of the system. Various electronic methods of control were considered, including photoelectric cells, radio-frequency devices, and conductivity circuits. The latter seemed to offer the simplest approach.

The Electronic Solution

Although stills use single-distilled water having a low conductivity it was felt that a sensitive relay might be employed which would operate under these conditions. A commercially available electronic relay of the hard-tube type was tried and, although it could be made to operate on the low currents available, it was not suitable for reliable, continuous operation because of the need for constant readjustment. It was felt that a more positive type making use of a gas tube could be constructed.

The action of the unit finally put in use and shown schematically in Fig. 2 is quite simple. When the circuit between T_1 and T_2 is open the gas tetrode is maintained nonconducting during the positive swing of the plate by applying to the grid through R_2 the negative swing from the filament-supply winding of the transformer. The phase is advanced slightly by the capacitance coupling to potentiometer R_1 in order to compensate for the lag introduced by the transformer. The exact amount of phase advance required is determined by individual transformer characteristics.

Tripping of the unit is accomplished by imposing on the grid a sufficiently large voltage in phase with the a-c line (or plate) voltage. This occurs when T_1 and T_2 are connected together. The resistance of this connection (single-distilled water conductivity) may be as high as 60 megohms. Protective resistors R_3 and R_4 may be increased up to

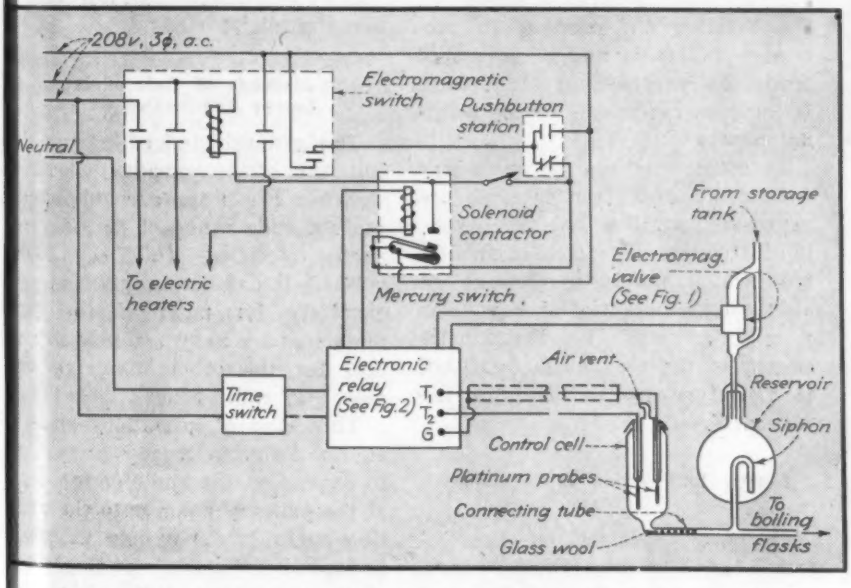


FIG. 3—Schematic of the complete still-control scheme, showing how platinum probes immersed in distilled water within the system provide the necessary conductivity path for operation of the electronic relay

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AUTOMATIC Of Stills

By R. E. SHRADER and E. J. WOOD

RCA Laboratories
Princeton, N. J.

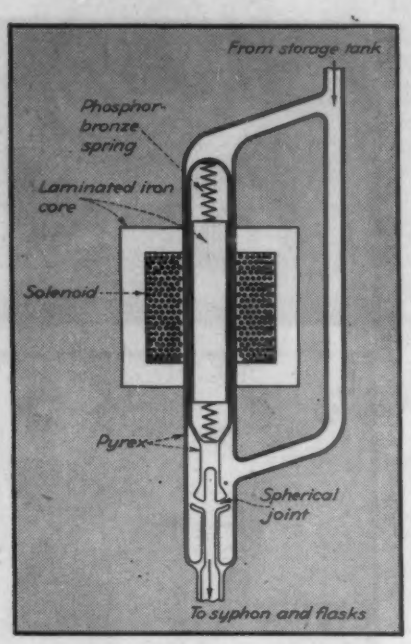


FIG. 1—Electromagnetic valve used to control the flow of water to the boiling flasks

SOME MATERIALS used in the field of electronics, such as phosphors, electron-emitting coatings and photosensitive surfaces, are of the impurity-sensitive type. The presence of one part in a million of a given impurity may alter some specific property by several orders of magnitude. It follows that any chemical research concerned with such materials will require reagents of the highest purity.

Since water is used in large quantities for almost all chemical manipulations, it is essential that a sufficient supply of very pure water be available. Three distillations will serve to produce water suitable for most uses. Our requirement of approximately 10 gallons per day of double-distilled water and five gallons per day of triple-distilled water makes it desirable that some sort of continuous system be employed which will operate with very little attention.

In the Laboratories, the primary distillation takes place in a conventional commercial still which feeds its product into a large glass-lined storage tank. From there the water is fed by gravity to the second stage of distillation. The second and third distillations are carried out in all-Pyrex stills, completely protected against airborne dust. The two glass stills are connected in series, the first being run at a rate approximately twice that of the second. Thus the first glass still delivers water directly to the boiling flask of the second, and the excess beyond that required to maintain a constant level passes through an overflow to double-distilled water storage. The second glass still delivers to triple-distilled water storage.

Two such combinations are in use and a fifth still is available to augment the double-distilled water production whenever it becomes necessary.

The Control Problem

The problem of automatic control comprises two phases: control of electric heater current, and control of the water level in the glass boiling-flasks. As the heater pow never exceeds seven kw at 110 v, ordinary electromagnetic switch capable of controlling the heat current. Control of the water lev however, is a more difficult matte To meet the requirements of an a glass system well protected again air-borne contaminants, a speci type of valve and level indicator required.

An electromagnetic valve d signed by Ralph H. Plumlee a constructed as shown in Fig. proved satisfactory. The valve of the vertical-lift type utilizing spherical ground-glass joint as se and plunger. A soft-iron laminate core is sealed inside the glass ste which extends into the center a surrounding solenoid. Energiz tion of the solenoid lifts the plunge permitting water to flow. When

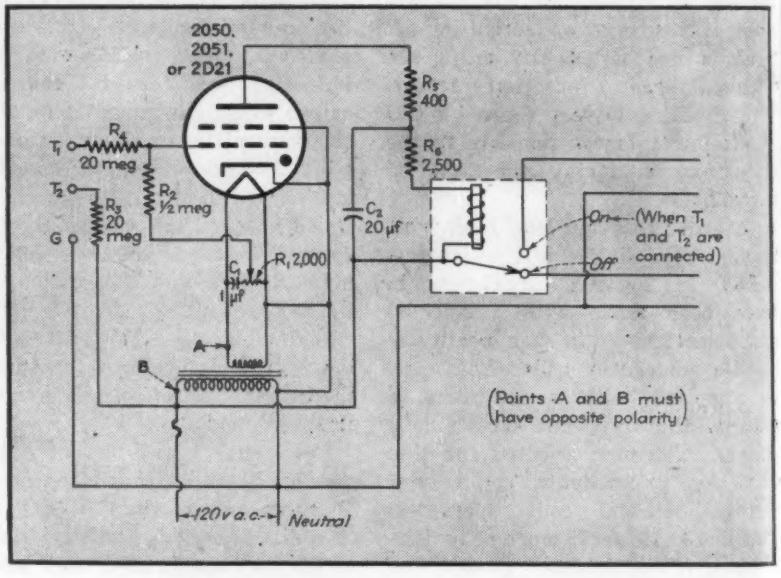


FIG. 2—Circuit of the electronic relay which operates the valve illustrated in Fig. 1 and an electromagnetic switch controlling current-flow to electric heaters beneath the boiling flasks

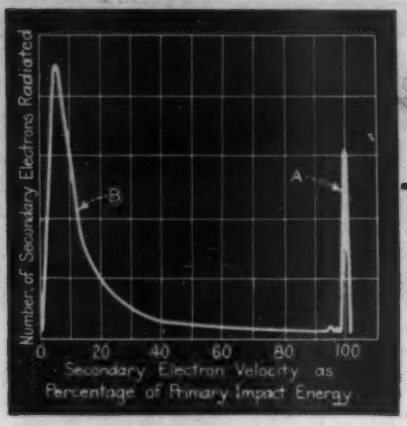


FIG. 1—Energy distribution of secondary electrons produced by the impact of primary electrons having a kinetic energy of 155 volts. The general shape of this curve holds between 20 to 10,000 volts

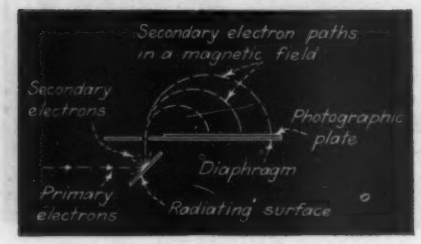


FIG. 2—Photographic method of determining the velocity distribution of secondary electrons. A magnetic field is assumed to exist in the space above the diaphragm, with a direction normal to the plane of the paper

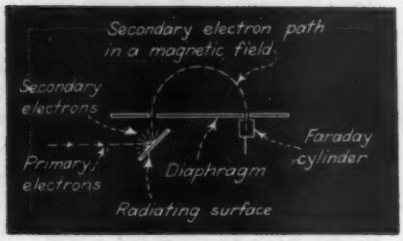


FIG. 3—Another method of arriving at the velocity distribution of secondary electrons. The magnetic field in this case is variable

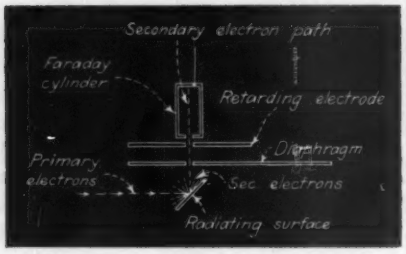


FIG. 4—The retarding potential method of arriving at the velocity distribution of secondary electrons radiated in a specific direction

SECONDARY E

By J. H. OWEN HARRIES

Electronics Department
Rediffusion Limited
London, England

WHEN AN ELECTRON current strikes an electrode surface, or, indeed, any surface, an emission of secondary electrons is produced. There is no known substance in which this effect does not occur. In fact, there is no substance which is known to act as a perfect absorber of any electrons which may impact onto it.

In electronic tubes, secondary radiation is sometimes useful, and sometimes undesirable. The phenomenon is complex, and information about it is scattered in various treatises many of which are commonly read only by those interested in pure physics. Most of these publications deal with the characteristics of secondary radiation, not from any interest in it for engineering purposes, but as a part of investigations into atomic structure.

This paper includes a survey of the existing information on secondary radiation and is presented from the engineering standpoint. It includes references to the original papers.

In most treatises on secondary radiation the electron energies are expressed in volts. The velocity, v, in centimeters per second of an electron which has fallen through an electrostatic potential of V volts is $v = 5.95 \times 10^7\sqrt{V}$. The kinetic energy of the electron is $\frac{1}{2}mv^2$ and is therefore proportional to the voltage V..

Energy Distribution of Secondary Electrons

In many publications on electronic engineering, as distinct from treatises on the physics of secondary electrons, it is sometimes stated that secondary electrons are radiated almost entirely at energies very low compared with the primary impact energy. This is not so.

A typical curve of energy distribution of secondary electrons is shown in Fig. 1. In this graph the number of secondary electrons radiated is plotted against the velocity (energy) with which the secondary electrons are shot out from a radiating surface. These secondary electron energies are plotted as a percentage of the primary impact energy. The primary impact energy is 155 volts. It will be observed that an appreciable number of secondaries are radiated at energies about equal to the primary impact energy, although there are a larger number radiated at very low velocities. Very thorough researches have been made during the last two decades into this question of secondary radiation energy distribution.[1-19]

Methods of Determining Energy Distribution Curve

The general kind of energy distribution of the secondary electrons shown in Fig. 1 appears to hold over quite a wide range of primary impact velocities (20 to 10,000 volts).[8] It has been confirmed very carefully for most of the pure metals, and is known to hold in general for the other materials employed in radio tubes.

This kind of secondary electron energy distribution does not appear to depend on the angle of incidence of the primary beam onto the emitting surface,[18, 20] nor does it appear to depend on the angle of emergence of the secondary electrons, though this point does not appear to have been quite so conclusively demon-

ELECTRON RADIATION

A thorough survey of existing American, British and other information on the subject, arranged for maximum usefulness to electronic engineers engaged in designing electron multipliers, dynatrons, beam tetrodes, pentodes and other tubes in which secondary electrons resulting from electron bombardment are either utilized or suppressed

strated by workers in this field.

In Fig. 2 an electron gun is arranged to produce a beam of primary electrons at a known velocity. The primary electrons are arranged to collide with a surface which then radiates secondary electrons. Some of the secondary electrons can pass through an aperture in a diaphragm into a space in which there exists a homogeneous magnetic field in the direction normal to the plane of the paper. It is a well known property of such a magnetic field that electrons traveling into it as shown will tend to describe circles the radii of which are given by

$$r = 3.37\sqrt{V_s/B} \qquad (1)$$

where B is the magnetic flux density, and V_s is the secondary electron energy in volts.

A photographic plate is positioned as shown. The number of electrons of any given velocity reaching the plate will be indicated by blackening at the appropriate place. This method, however, is not very practicable, because the sensitivity of a photographic plate is rather low.

A Faraday cylinder, which has the property of trapping electrons and the secondaries they produce, can be substituted for the photographic plate as in Fig. 3. By varying the magnetic field, the number of secondary electrons of each velocity may be found.

Another method, shown in Fig. 4, does not use a magnetic field, but instead, employs a retarding potential to sort out the secondary electrons in terms of their energies. The primary electrons hit a secondary radiator at a known energy, and secondary electrons pass through a diaphragm into a Faraday cylinder. The amount which are able to enter depends upon the potential of a retarding electrode positioned as shown and upon the initial energies of the secondaries themselves.

The arrangement of Fig. 5 enables the energies to be obtained for the secondary electrons at all angles. The primary electron beam strikes a radiating surface which is at the center point of a collecting sphere. A retarding potential is applied to this sphere, and the number of electrons reaching it is measured as a function of this potential.

In the arrangements of Fig. 4 and 5, the energy distribution curve is obtained by differentiation of the curve of current to the Faraday cylinder or collection sphere as a function of the retarding potential.

Interpretation of Curve

The general results of all these methods agree. The particular curve shown in Fig. 1 is given by Rudberg[1] and is obtained by the magnetic method.

It is generally agreed that the energy distribution curve of Fig. 1 may be interpreted as follows: Peak A represents that portion of the emergent electrons which retains the full primary energy. At secondary electron velocities between about 98 and 50 percent of the primary velocity, the number of secondary electrons radiated does not change much with the secondary electron velocity. Large quantities of secondary electrons are emitted with low velocities, as indicated by peak B, but the number emitted drops rapidly as secondary velocity approaches zero (at secondary energies of the order of tenths of a volt and less).

Peak A of the curve is produced by electrons which emerge after being elastically reflected. They result from diffraction unaccompanied by loss of energy to the atoms which are being bombarded by the primary electrons. All other parts of the curve are produced by secondary electrons which have been deflected by repeated collision accompanied by considerable energy loss.

Those secondaries contributing to parts of the curve other than A are usually referred to as emitted or true secondary electrons. Those contributing to part A of the curve are usually referred to as reflected electrons. For this reason the phenomenon as a whole is usually referred to as secondary radiation, and the words emitted and reflected are reserved for the special meanings set out.

Action at Low Impact Velocities

With primary impact velocities below about 10 volts it has been found that the energy distribution of Fig. 1 does not hold. The secondary radiation consists almost entirely of reflected electrons which retain the full primary energy, so that the whole of the radiation is contained in a peak like A on Fig. 1.

The percentage of emitted secondary electrons to reflected secondary electrons increases steadily up to primary velocities of the order of 1000 volts, after which it falls once again. As previously mentioned, however, the general shape

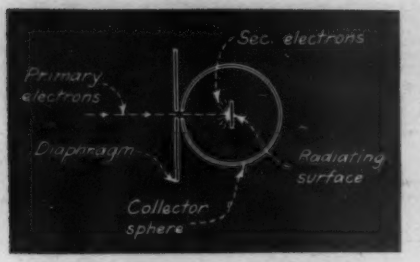


FIG. 5—The retarding potential method of arriving at the velocity distribution of secondary electrons emitted and reflected from a radiating surface

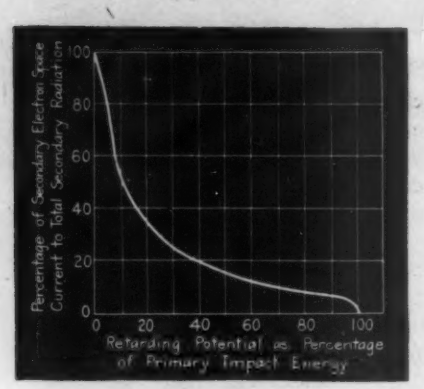


FIG. 6—Ratio of secondary electron current travelling to a collector and the total secondary radiation, plotted as a function of the retarding potential between the radiator and the collector

of Fig. 1 holds between about 20 and 10,000 volts.

Space Potential Considerations

It is important to realize that under electrostatic conditions the velocity of each of the secondary electrons at any point in space will be determined by the space potential V of that point. It follows that an electron emitted at a velocity which corresponds to a voltage V_s will be brought to rest at any point in space where a negative space potential $-V$ numerically equals V_s. This is the principle by which secondary electrons are sorted into their respective velocities (or energies) by means of the retarding electrode or collecting sphere of Fig. 4 and 5 respectively. A potential which is arranged in this way to stop secondary electrons is generally referred to as a retarding potential.

Figure 6, which is obtained by integration of Fig. 1, shows the ratio of secondary electron current to any collector (such as the collector sphere in Fig. 5) to the total secondary radiation current as a function of the retarding potential. This potential is expressed as a percentage of the impact energy in volts.

In pentodes and beam tetrodes, the prevention of the flow of secondary electrons is one of the primary objects of the tube design. With reference to Fig. 5, it will be realized that if the collector sphere is at a potential (with respect to the cathode) which is 90 percent of the impact potential of the radiator (also measured in volts with respect to the cathode), then a retarding potential of 10 percent will exist between the collector sphere and the radiator. Figure 6 shows that under this condition the secondary radiation current flowing to the collector electrode will be 54 percent of the total secondary radiation from the radiator.

All this, of course, assumes quasi-steady-state conditions as regards voltage, (i.e., that the voltage does not vary rapidly with time), and that no appreciable space charge due to the primary or secondary electrons exists in the space between the emitter and the collector sphere. The physics measurements quoted in this paper are all made under static conditions, and care has been taken to avoid space charge effects, but these effects must not be forgotten when applying the information to practical radio tubes. Such tubes when in operation are very seldom free from space charge effects.

TABLE I. MAXIMUM TOTAL SECONDARY RADIATION COEFFICIENTS

Secondary emitter	Max. value of sec. radiation coeff.	Primary impact velocity (volts) at which max. of sec. radiation coeff. occurs
Caesium (compound layer)	8.5	400–600
Rubidium(compound layer)	5.75	700
Beryllium	5.4	600
Calcium	4.95	520
Barium	2.72	530
Potassium(compound layer)	2.5	600
Aluminum	2.4	400
Silicon	1.63	380
Platinum	1.52	1000
Silver	1.47	800
Gold	1.45	780
Tungsten	1.33	625
Nickel	1.3	500
Tantalum	1.3	625
Copper	1.27	600
Iron	1.27	400
Molybdenum	1.27	375
Niobium	1.17	400
Carbon (lampblack)	0.6–1	...

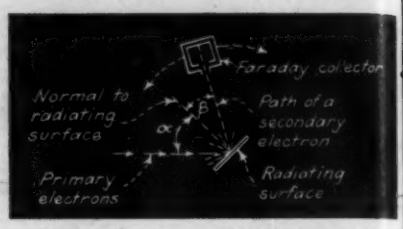


FIG. 7—Use of an angularly adjustable collector to measure the secondary radiation coefficient of both reflected and emitted electrons as a function of the angle of emission to the normal

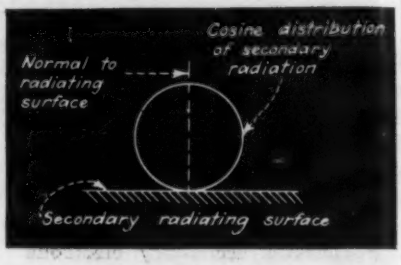


FIG. 8—Distribution of secondary electrons as a function of the angle β of secondary radiation

Some relationship exists between the secondary energy distribution curve and the material of the emitter. This has been found by Sharman[15] to be in agreement with the atomic properties of the material. At voltages of the order of 8000 volts, however, Stehberger[21] failed to find any such connection. The answer to this question is rather vague at present.

Angular Distribution of Secondary Radiation

The relative amount of secondary radiation at various angles from a surface may be determined by apparatus such as that illustrated in Fig. 7. The Faraday collector is rotatable with respect to the radiating surface. The angle of incidence of the primary electrons to the normal of this surface is indicated by α and the angle of secondary radiation by β. The number of secondary electrons per unit angle may thus be determined.

Measurements of angular distribution have been carried out by a number of workers.[21, 22, 23, 24, 25] While there is some experimental evidence[26] of optical reflection of the primary electrons (i.e., $\alpha = \beta$), the

vidence of this effect is by no neans generally accepted. At present it seems reasonable to assume cosine distribution of secondary adiation, as shown in Fig. 8; that s, the intensity of the secondary adiation varies as cos β, and this istribution is virtually independent of α. The maximum value of he secondary radiation varies, however, with α. This effect is discussed n greater detail later.

otal Secondary Radiation Coefficient

The arrangement of Fig. 5 may learly be used for measuring the otal radiation of secondary electrons if the collector sphere is at a slightly higher potential than the radiating surface. This measurement is in fact a summation of the curve of Fig. 1, and gives the ratio between the total number of secondary electrons and the total number of primary electrons striking the emitter. This ratio is generally referred to as the total secondary radiation coefficient. It must always be remembered, when interpreting values of this ratio, that in all cases a velocity distribution must be assumed. In the case of impact energies between about 10 volts up to the order of 10,000 volts, this distribution would be that of Fig. 1.

In practical electronic devices the actual ratio of secondary electron current to a given electrode near the emitter to the primary electron current will depend (among other things) upon this velocity distribution. Not all the secondary electrons necessarily contribute to the secondary electron current.

The total secondary radiation coefficient plotted against the primary electron impact energy was one of the characteristics to be investigated by the earliest workers.[26-30]

Secondary Radiation Coefficient of Pure Metals and Carbon

Typical measurements of the total secondary radiation coefficient are shown in Fig. 9A and 9B. These curves have been confirmed by many investigators. The curves rise to a maximum and then fall as the primary impact velocity increases still further. The maximum value of coefficient obtained lies between about 1.2 and 5.5 in the case of pure metals. Its highest value is of the order of 8 to 11 for compound surfaces of caesium of the kinds used in secondary electron multipliers and the like. Not many substances have coefficients of less than unity. That for carbon varies between 0.6 and 1.0.

Provided that the metal surfaces are clean and are completely degassed, the secondary radiation coefficient is found to be about the same by many different investigators.[31-39]

Table I (from Kollath[40]) shows typical values of the maximum secondary radiation coefficient, and the values of primary impact energy at which it occurs, for a number of substances.

Secondary Radiation Coefficient of Evaporated Layers

Copeland[22, 25, 41] has obtained interesting results by evaporating various substances onto a metal foundation. Evaporating caesium onto gold increased the secondary radiation coefficient of the combination several times over that of gold alone. He also investigated other combinations of layers and foundations. The results appear to be explainable in terms of the degree of penetration of the primary electrons through the surface layer, and the varying absorption of the secondary electrons by the different substances used.

Secondary Electron Coefficient of Composite Surfaces

It was found[25] that composite materials have a high secondary radiation coefficient. For instance, evaporated deposits of calcium onto gold, and lithium onto tantalum, produce coefficients of the order of

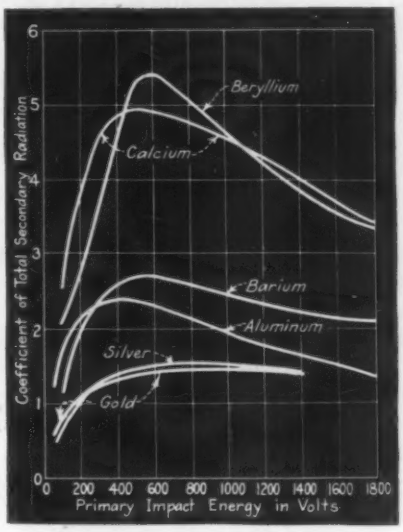


FIG. 9B—Coefficient of total secondary radiation as a function of primary impact energy for various substances

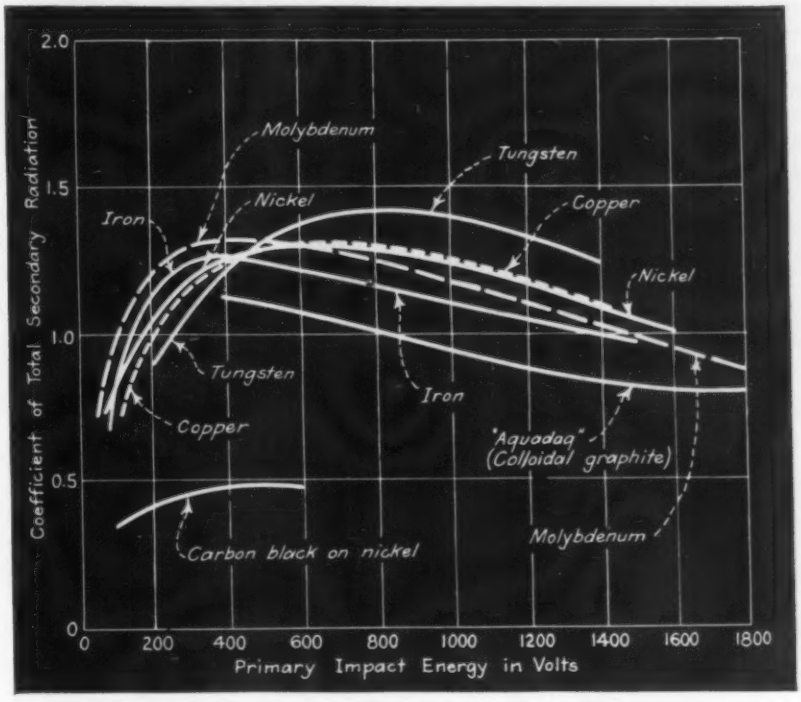


FIG. 9A—Coefficient of total secondary radiation as a function of primary impact energy in volts for the materials commonly used in vacuum tubes

4 to 5. It was observed that calcium and lithium belong to the alkaline-earth group of metals. They have low work functions and they have a high thermionic and photoelectric emission. An investigation of caesium/caesium-oxide/silver was a natural step, and high secondary electron coefficients resulted. It was discovered, however, that neither a low work function nor a high photoelectric sensitivity is the only factor concerned in producing a high secondary electron coefficient. Typical results for composite surfaces on silver are shown in Fig. 10.

The following table is given by Weiss[42] for various values of the maximum secondary radiation coefficient for caesium/caesium oxide deposits on various metal foundations.

The processing of the layer produced is of great importance. The deposit used as the composite surface is probably of the order of monoatomic thickness.

In detail, the production of secondary electron emissive surfaces is, like the production of coated thermionic cathodes, largely an empirical process.

Secondary Radiation Coefficient of Insulators

There is comparatively little information in this matter, but it seems[24, 45] that secondary emission from insulators consists largely of electrons that have a low velocity compared with the primary electron velocity. The cosine law of distribution appears to hold, and the coefficient can exceed unity. There is, however, a difference with regard to the angle of incidence of the primary electrons impacting the radiator. In the case of conductors, the secondary radiation coefficient increases continuously with the angle of incidence, but in insulators this is not so. The coefficient increases up to a critical angle of incidence in either direction from 0 deg, beyond which the coefficient drops sharply and then again increases, as shown in Fig. 11.

This critical angle has been found to be evident only at certain levels of primary impact velocity in the range from 1300 to 3000 volts. The critical angle increases with increasing voltage, and eventually vanishes. It is also affected by temperature. For example, a critical angle which is 35°C at room temperature falls to 15°C at the temperature of liquid air. It vanishes at 150°C. At this and higher temperatures, the phenomenon is the same for insulators as for conductors.[24, 43, 44-50]

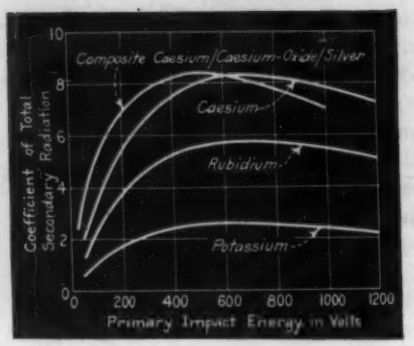


FIG. 10—Coefficient of total secondary radiation as a function of primary energy in volts for pure metals and a composite oxidized layer on silver

Explanations [21, 51, 52] assume that a surface layer of negative space charge is produced on the insulator and affects the emission of secondary electrons. An insulating surface does not necessarily have a negative charge, however. The charge will depend upon the conditions of the experiment and upon the secondary radiation coefficient of the material.

Variation of Secondary Radiation Coefficient With Primary Angle of Incidence

In general, at low primary impact energies (up to about 100 volts or so), the secondary radiation coefficient is the same for all angles of incidence.

TABLE II. MAXIMUM SECONDARY RADIATION COEFFICIENT FOR CAESIUM LAYERS ON VARIOUS METAL FOUNDATIONS

Metal	Max. value of sec. radiation coeff.	Primary impact energy (volts) at which max. of sec. radiation coeff. occurs
Silver	8- 11	600
Magnesium	6.8- 7.5	700
Tantalum	4.1- 5.5	600
Zinc	4.5- 5.4	600
Nickel	4.6- 5.2	550
Aluminum	4.4- 4.7	600
Copper	3.5- 4.0	600
Tungsten	3.8- 3.9	600
Lead	2.3- 3.3	650
Molybdenum	2.5- 3.1	500
Iron	1.9- 2.7	500
Gold	2.3-	600

At higher voltages this is not so. A typical result due to Müller[45] is for a primary impact energy of 2500 volts, and is shown in Fig. 12. It is interesting to note (Kollath[46]) that if the coefficients for various metals are plotted in order of increase of coefficient with incidence, they will then be arranged more or less in descending order of their specific gravities. The secondary radiation coefficient, as a function of the angle of primary incidence to the normal, rises with decreasing specific gravity. [53-58] The results previously described apply to angles of incidence in the neighborhood of the normal unless otherwise specified.

Secondary Emission at High Primary Impact Velocities

Primary impact energies have been investigated which are very much greater than the few thousand volts to which the previous remarks have been confined, but high-voltage results differ little. The velocity distribution curve of Fig. 1 is affected only insofar as peak A increases in relative area (that is, the reflected electrons increase in number).[20, 21, 25, 57, 58]

The secondary radiation coefficient as a whole falls with increasing primary impact energies. The increased penetration of the primary electrons of high velocity into the metal results in the secondary electrons being reabsorbed in the surface layers of the material. This fall in secondary radiation coefficient is to some extent counteracted by primary electrons which emerge in a direction different from the normal to the surface, and cause secondary electrons to be emitted from the surface layer of the material. In fact, this latter effect predominates in producing secondary radiation at very high values of primary impact velocity.[21] The angular distribution of the radiation follows the cosine law.

Consideration of the depth at which emission is produced is of considerable importance where radiation is obtained from both sides of a thin foil through which primary electrons are arranged to pass.[8]

Many investigators[7, 18, 59-63] have shown that the structure of the radiating surface has considerable effect on the coefficient. No effect on

it is noted by Hayakawa[61] at the magnetic transformation points of ferro-magnetic materials, but sudden changes have been shown to occur at the points of allotropic modification of the surface structure. An abrupt variation in the secondary radiation coefficient of iron at the Curie point has, on the other hand, been recorded by another worker.[62]

Further Investigation Needed

According to Rao[63], a nickel monocrystal gives a lower secondary radiation coefficient than an ordinary polycrystalline nickel surface. An opposite result is obtained by H. E. Farnsworth[7] with respect to copper. His result appears to agree with the experimental fact that the secondary radiation coefficient of finely precipitated carbon or platinum black has a particularly low coefficient of secondary radiation.

Further investigation seems to be needed. In the meantime it seems that either monocrystal surfaces of different materials have different effects on the coefficient, or that there is perhaps some optimum size of crystal which gives a maximum coefficient.

Effect of Temperature on Secondary Electron Coefficient

As far as can be ascertained there is no temperature effect. According to Kollath[60] this point might, however, be worth further investigation, particularly with regard to the complex surface coatings now commonly used in commercial practice.

Effect of Gas on Secondary Radiation Coefficient

All materials contain a certain amount of gas before they have been heat treated by the usual valve (tube) manufacturing processes which are necessary to produce a high vacuum. Occluded gas has a considerable effect on the secondary radiation coefficient, and until the radiator is completely degassed repeatable results are not obtained. Measurements on the effect of gas have been made by Farnsworth,[7] Warnecke,[28] and Ahearn.[64] In general, the presence of gas increases the secondary radiation coefficient, often several times.

Mechanism of Secondary Electron Radiation

The quantitative analysis of the atomic mechanism of the phenomenon is in a very rudimentary state. In fact, a survey of the subject reduces itself largely to an unsatisfactory recital of disjointed experimental facts rather than to a coherent statement of theory. Kollath's paper[60] gives an excellent outline of the situation up to 1937. The relationship between secondary radiation phenomenon and the atomic structures of various metals gives no very conclusive result, nor has the work function any very useful relationship, though there has been shown to be some proportionality between the secondary radiation coefficient and this quantity. The depth of penetration of the primary electrons has been estimated, and Becker[14] arrives at a calculated depth of penetration of about 30 Angstrom units (about 15 to 20 atomic layers) at primary impact velocities of the order of 500 volts.

Emission Time of Secondary Electrons

As far as the author is aware, no measurements or computations of this quantity have yet been made. It may prove, however, to be very important in view of the increasing use of extremely high frequencies in electronics. So far, the only conclusion appears to be—and this is a unanimous one[65-72]—that the time of emission is less than 10^{-9} second. This is as much as several times the periodic time at the highest radio frequencies now being brought into use. Modern ultra-high-frequency technique might enable the time to be measured. A suggestion due to Kollath[60] involves comparing the times of arrival of electrically reflected primary electrons with those of secondary electrons. Experimental difficulties, appear, however, to be considerable.

Secondary Emission Transit Times

In view of the initial velocity spectrum (Fig. 1) common to all secondary radiation (the fact that secondary electrons are not all emitted at the same velocity), secondary electrons traveling from the emitter to another electrode do so with differing transit times. This effect is of substantial importance to the operation of vacuum tubes at very high frequencies, and is dealt with later in this paper.

SECONDARY RADIATION IN ELECTRONIC ENGINEERING

In electronic engineering, secondary radiation is sometimes found to interfere with the desired operation of the radio tube in which it occurs. Sometimes, on the other hand, it is utilized as an essential part of the mechanism of operation

The Dynatron Valve

In a tetrode valve, when the screen grid is at a higher potential than the anode, secondary radiation from the anode may travel to the screen grid and produce a negative resistance characteristic in the anode circuit over a range of anode voltages. Hence the valve can be made to generate oscillations. This effect was first described by Hull.[73] In considering these results with

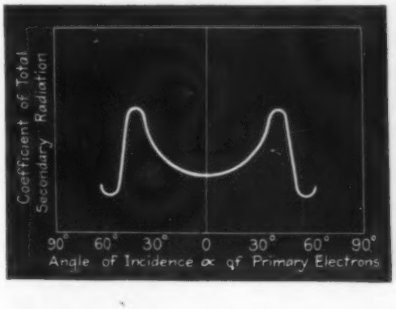


FIG. 11—Coefficient of total secondary radiation from an insulator as a function of the angle of incidence of the primary electrons. A critical angle of incidence will be observed

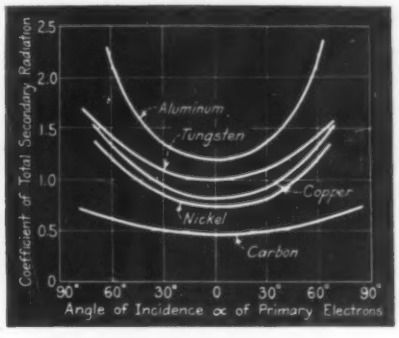


FIG. 12—Coefficient of total secondary radiation from various conductors as a function of the angle of incidence α of the primary electrons. The primary impact energy is 2500 volts

Primary electrons pass through the spaces between the suppressor grid wires. A retarding potential exists between these spaces and tends to reduce the secondary radiation current from the anode to the screen grid to a fraction of the primary electron current (see Fig. 4 and 6). At the same time, due to the cosine law of distribution (Fig. 8), only a small number of the secondary electrons are directed towards the gaps in the suppressor grid. This results in a still further reduction of the total secondary electron current.

A further effect which tends to reduce the adverse flow of secondary electrons is the addition to the retarding potential caused by space charge effects. Both primary and secondary electrons contribute to the space charge potential. The combination of all these effects (and possibly others) operates in a very complex manner, and the author is not aware of a satisfactory quantitative theory, but pentode valves may readily be designed by empirical means.

Remembering that the potential of the spaces between the wires of the suppressor grid cannot be zero (or the primary electrons themselves would be prevented from arriving at the anode), it is untrue to say that the operation of a pentode is explained merely by the interposition of a retarding potential between the anode and screen grid. A retarding potential which did not reduce the potential between the wires of the suppressor grid to zero would still leave a considerable amount of secondaries flowing. This is clear from Fig. 6. Curve A in Fig. 15 shows the familiar dynatron characteristic which is produced in the absence of a suppressor grid. Curve B shows the characteristic found in a pentode, and curve C shows the type of characteristic that might perhaps be expected if the suppressor grid retarding potential alone were the only operative factor in preventing the flow of secondary electrons.

Secondary Electron Traps

Due to the cosine distribution of secondary radiation (Fig. 8), if a beam of primary electrons enters an enclosed metal cavity (at a positive potential) through a small aperture as in Fig. 16, only a very small part of the resulting secondary radiation will succeed in leaving the cavity. This is the principle of the Faraday cylinder previously referred to (Fig. 3, 4, and 7). Attempts have been made and suggested[30] to utilize such cylinders as the anodes or collector electrodes of practical radio tubes. Since in such radio tubes the effective anode area for the collection of primary electrons must usually be considerably greater than the small aperture illustrated in Fig. 16, these attempts have not been very successful as far as the author is aware.

Critical-Distance Beam Tetrodes

In 1931 the author, working on the production of the then novel idea of producing beams of electrons of appreciable fractions of an ampere at a few hundred volts, found that if the space current in a dynatron type of tetrode is confined into a beam, an optimum value exists for the distance of the anode from the screen grid (accelerating grid; he named this distance the critical distance) at which the passage of secondary electrons from the anode to the accelerating grid is prevented. The anode characteristic then obtained is of the kind illustrated in Fig. 17.[30-36] The sharp knee at the lefthand side of the curve is characteristic of this type of tube and results in a considerably lower distortion level[35, 36] than the more rounded knee of the pentode (Fig. 15).

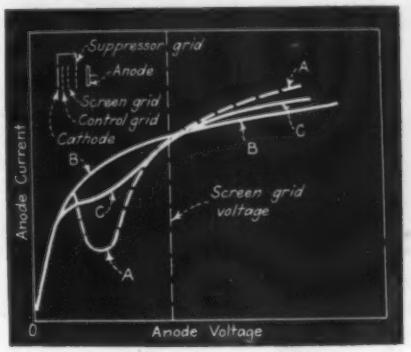


FIG. 15—Curve A is the anode characteristic of a dynatron valve. Curve B is that of a pentode. Curve C is the approximation to the kind of curve that might be expected if a suppressor grid is assumed to operate solely by producing a retarding potential

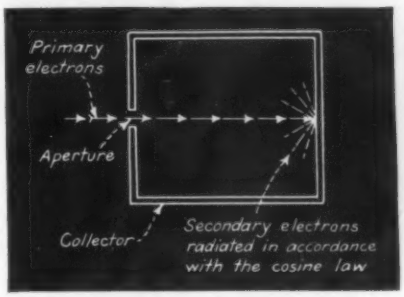


FIG. 16—A Faraday cylinder or electron trap

Tubes of this kind were made in 1931 and were put on the market in England by a commercial firm in 1935. They came into wide use, under the name of beam tetrode when this tube was first marketed (in America) in 1936; yet, like the pentode (the invention of which dates from 1926), there is again no satisfactory published theory. The straight part of the anode characteristic of this valve (Fig. 17) can only be accounted for by the reduction of the traverse of secondary radiation to a very small fraction indeed of the total radiation. By reference to Fig. 6, it will be seen that this appears to infer a retarding potential virtually equal to the primary impact velocity itself.

Attempts have been made to explain this critical-distance characteristic in terms of the potential minimum produced by space charge,[35, 36] but the author has shown[36] that the magnitude of the retarding potentials predicted by this theory is not sufficient (by a factor of several times) to prevent the occurrence of the dynatron kink in the anode characteristics. Moreover, the problem is not merely one of preventing the passage of secondary radiation at one set of values of anode current, anode voltage, and screen voltage. It is, on the contrary, that of maintaining a flat working surface of the characteristic over a wide variation area (Fig. 17). A purely space-charge retarding potential theory leads to no such range of working currents and voltages.

A complete formulation of the problem must include the effects of the formation of the primary electrons into a beam (without which the effect seems not to take place in practice), the variation of the density of this beam with control grid voltage, the energies of the

respect to modern radio techniques due regard must be paid to secondary radiation transit angle effects.

Secondary Electron Multipliers

Secondary electron multipliers[74] of both the magnetic and electrostatic types are so well known that it is unnecessary to describe them in detail. In multipliers, the primary electrons strike an emissive surface which is of such a kind as to produce a high ratio (usually between 8 and 11) of total secondary radiation coefficient. Secondary electrons thus radiated are caught by another plate from which further secondaries are again radiated. This process is repeated several times in order to produce a very high total magnification of the original primary electron beam current.

The primary electron beam can be controlled by either photoelectric effects[75] or by voltage control. Greater importance appears to attach to the amplification of photoelectric currents than to voltage control, as the limitations of the latter type cause it to be rather specialized in application.[76] An interesting and comparatively recent example of voltage control has been described by Wagner and Ferris.[77] Control of the primary electrons in secondary multipliers by deflecting them instead of using a control grid appears to have been first described by Hopkins.[78] The composite caesium/caesium-oxide/silver curve in Fig. 10 shows the ratio of secondary emission current to primary current obtained from one of the radiating surfaces in a multiplier.

Since secondary electrons are not emitted with a single velocity, but with a spectrum of velocities, the transit angle between the radiators in the multiplier also has no single value.

In Fig. 13, the ordinates represent the relative number of secondary electrons emitted at each of various relative overall transit angles of the secondary electrons in a 3-stage electron multiplier. The relative overall transit angle is expressed as a fraction of the transit angle which would exist if the secondary electrons were emitted with zero velocity. It will be observed that the transit angles of the individual secondary electrons vary over a wide range. Furthermore, secondary electrons are radiated from different parts of the radiator, and have to travel along paths of different lengths to reach the next electrode.

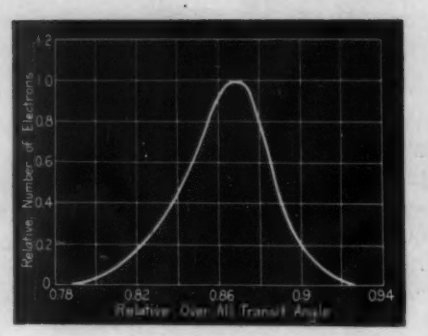


FIG. 13—Variation of transit angle of secondary electrons in a secondary electron multiplier. This variation is due to the distribution of secondary electron energies illustrated in Fig. 1. Note that this graph ignores peak A of Fig. 1

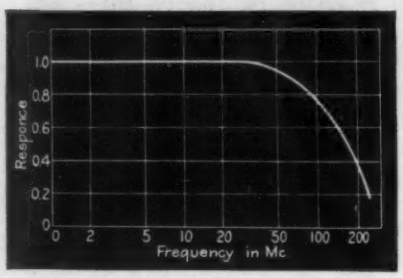


FIG. 14—Frequency response of an electron multiplier, showing fall-off at very high frequencies due to the transit angle effect illustrated in Fig. 13

The result of these combined effects has been shown by Malter[27] to produce a high-frequency cut-off in the response of the multiplier as a whole. The resulting frequency cut-off of a typical multiplier is shown in Fig. 14.

Farnsworth Multipactor

Another application of secondary electron multiplication involves the utilization of transit time to produce high-frequency oscillations. This idea was first put forward by Philo T. Farnsworth.[79]

Reduction of Screen Grid Current

In many screen-grid radio tubes the anode is maintained during operation at a potential higher than that of the screen grid. Secondary radiation of quite a considerable amount is produced at the points of impact upon the screen grid of the primary electrons which constitute the space current. The secondary electrons travel from the screen grid to the anode and so decrease the screen grid current, and increase the anode current, very considerably. This results in an increase in the static transconductance of the tube. It must not be forgotten that due to the varying transit angles of the secondary electrons, this increase will not hold at very high frequencies. The phenomena produced will be somewhat similar to that exemplified above with respect to secondary electron multipliers. There seems to be no published information in this matter.

Secondary Radiation from Cathodes

In certain tubes—notably the magnetron—the cathode may be bombarded by primary electrons which return to it at considerable velocities. By adding to the emission, the resulting secondary radiation may have an appreciable effect on the operating characteristics of the valve.

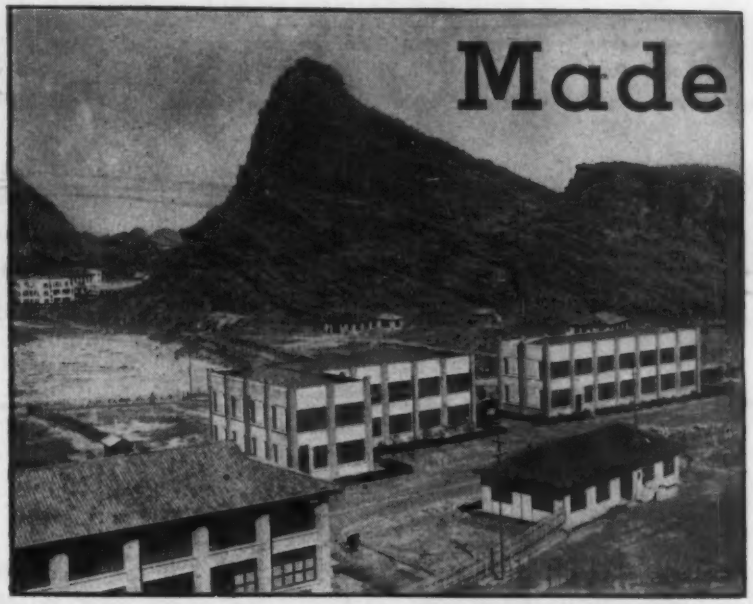
The Pentode

In the great majority of electronic tubes, secondary radiation is a nuisance and elaborate steps have to be taken to prevent it from interfering with the operation of the tubes. It will be clear from Fig. 5 and the associated text, however, that attempts to prevent the radiation of secondary electrons from the electrodes of radio tubes are foredoomed to failure. In fact, quite early engineering experiments confirmed this.[80]

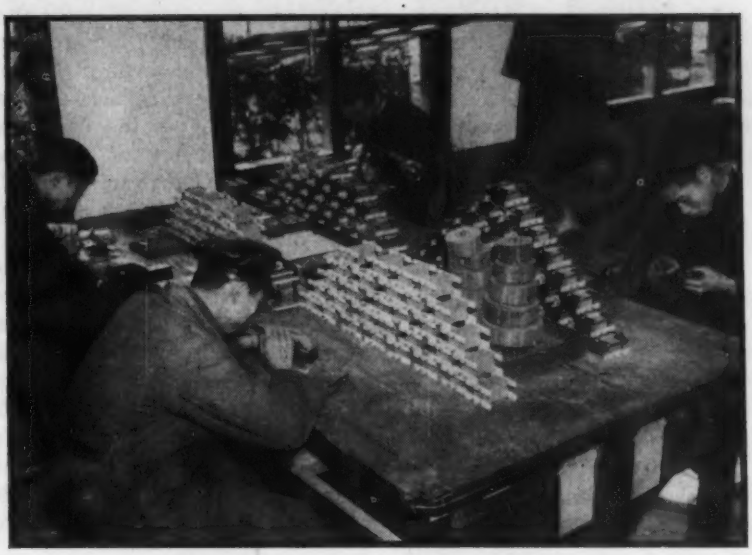
Since secondary radiation itself cannot be prevented, the only remaining thing to do is to prevent the secondary electrons traveling from one electrode to another. This is the idea behind the pentode.

It is almost unnecessary to describe this well-known tube in detail.[81] The traverse of secondary electrons from the anode to the screen grid when the anode is at a lower potential than the screen grid during operation is prevented partly by the use of a retarding potential. A grid (called the suppressor grid) is interposed between the screen grid and the anode and is maintained at a low potential.

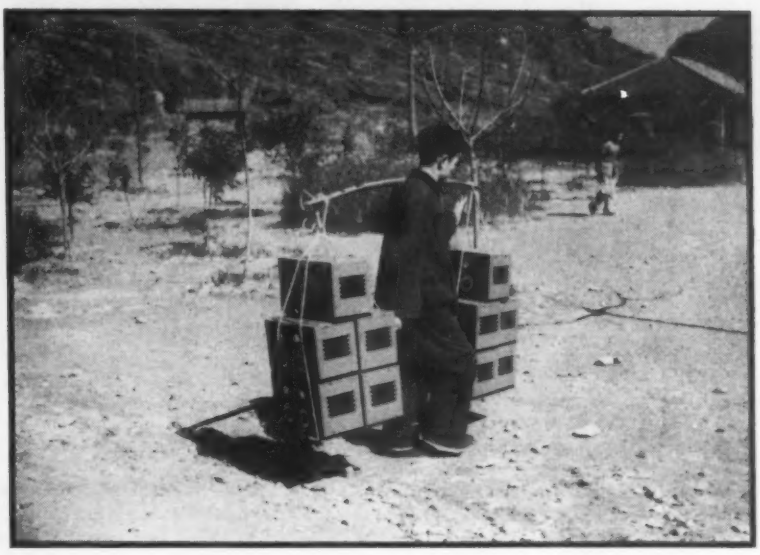
Made in CHINA



In this rugged terrain near Kweilin, capital of Kwangsi Province, native workers make radio equipment used by the Chinese Army and Government-operated broadcast stations. Known as the Central Radio Works, the plant is operated by the National Resources Commission. Note parking lot



Components are assembled as above where capacitors and vacuum tubes receive the dextrous attention of Chinese employees. Below, a worker finishes up the wiring on a transmitter, while a coolie, right, forms the local version of a conveyor line in transporting units around the plant



secondary electrons, the angular distribution of the secondary radiation, the end effects, and the depression of space potential due to the presence of low-potential conductors near the screen grid-anode space. (An approximate theory of the beam tetrode can, however, be produced to take these factors into consideration, and the author hopes to present it in due course when war-time matters permit.)

It has been pointed out by the author some time ago[20] that if the accelerating voltage is higher than a few hundred volts, the critical-distance effect is not produced satisfactorily. This appears to have a relationship to the increase in the area of peak A in the secondary radiation energy distribution curve (Fig. 1) at the higher primary impact velocities.

Secondary Emission from Grids

Grids and other electrodes in electronic tubes which are struck by electrons will emit secondaries which, particularly in tubes where optical images are to be formed, may be very undesirable. Such effects may be minimized, though not eliminated, by treating the surfaces involved. Coating with carbon black or like methods are used (Fig. 9A).

Secondary Radiation from Insulated Electrodes and Insulators in Vacuum Tubes

If an insulated conductor is positioned in the path of a beam of primary electrons, its potential will depend upon the impact energy of the primary electrons and upon the secondary electron coefficient of the conductor.

For instance, referring (Fig. 9A) to the curve for nickel, it will be seen that it becomes unity at a primary impact velocity of approximately 1750 volts. The initial potential of a clean insulated electrode made of nickel will, in the absence of a flow of primary electrons, be that of the space in which it is situated. If this potential, and the impact energy of the primary electrons upon the nickel electrode are both above 1750 volts, then, from Fig. 9A, the total secondary radiation coefficient will be less than unity. The insulated nickel electrode will therefore charge negatively until its potential reaches 1750 volts, when the secondary radiation coefficient is unity, and the number of electrons leaving the electrode will be equal to those reaching it. This, of course, assumes space-charge-free conditions, and assumes further that all the secondary electrons emitted by the nickel are collected by other electrodes in the tube.

If, again, the space potential of the insulated nickel electrode and the initial energy are between about 160 and 1750 volts, then, from Fig. 9A, the secondary radiation coefficient will be greater than unity, and the electrode will tend to charge positively until an equilibrium potential of about 1750 volts is again reached.

If, however, the space potential and the primary impact energy are below 160 volts, then, from Fig. 9A, the total secondary radiation coefficient is less than zero. The insulated electrode will charge up negatively until it reaches zero potential, at which no primary electrons strike it. Therefore, in general, an insulated conductor upon which electrons impinge tends to take up either a potential tending to zero, or a high positive potential. It has been suggested to employ this effect to maintain a suppressor grid in a pentode at the order of zero potential. Clearly, if the electrode is contaminated, or otherwise has a greater secondary radiation coefficient than the pure material (and this may very easily occur in a practical radio tube), the impact potential at which the total secondary radiation coefficient is unity may well become very high.

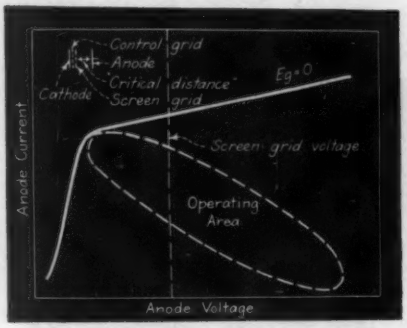


FIG. 17 — A critical-distance beam-tetrode characteristic

The equilibrium potentials of insulators (such as the glass walls of a vacuum tube) due to secondary radiation may vary discontinuously and profoundly affect the space potential in the tube as a whole, and therefore in many instances upset the operation of the device. In the absence of more information on the secondary radiation coefficients of insulators, and because of the complicated nature of their behavior, it is not possible to state any useful theory. In radio tubes care is taken to minimize the results of bulb charging. This is done by causing the electrode assembly to be self-shielding (i.e., semi-enclosed as far as the operative part of the electron beam is concerned) or by putting a conductive film (such as collodial graphite) on the walls of the glass envelope and connecting it to a suitable part of the electrode system. This is found to be necessary in cathode-ray oscilloscope tubes where the beam is not enclosed by the metal electrodes.

Conclusion

It is remarkable, considering the extreme importance of secondary radiation in electronic engineering, that there are so many gaps in the published information and theory. The author would appreciate any additions or corrections to this paper.

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(*Continued on page* 180)

PHOTOTUBE CONTROL

Flow rates as constant as ± ¼ percent are achieved by a system which combines a rotameter for light-source interruption with phototubes, amplifiers, and thyratrons to control a motor-driven regulating valve

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ROTAMETERS are simple instruments which accurately indicate the rate of flow of liquid or gas in a pipe line. They are widely used in chemical process, power, and other industries. The instrument, shown in Fig. 1, usually consists of a vertical, transparent, tapered, glass tube and a metering element inserted inside the tube. The small end of the tube is at the lower portion, and the metering element, variously shaped depending upon fluid requirements, is free to move up or down along the axis of the tube. The position assumed by this element directly indicates flow rate. The gas or liquid being metered flows from the bottom to the top of the tube.

Theory underlying the operation of this type of flow indicator is based on the flow equation, $Q = CA\sqrt{2gh}$, where h is a constant by virtue of the constant net weight of the metering element (commonly called the float or rotor), and A is a variable due to the taper of the tube. The force counter to the float weight is the head differential induced by the fluid flowing through the annular aperture between the outside diameter of the float, and the inside diameter of the tube. Thus the rate of flow varies directly as annular area and the calibration of the instrument is linear.

In other words, forces on the float are in balance; weight of the float minus buoyancy equals area of the top of the float, times differential pressure. If the flow rate increases, the differential across the float will increase, and the float will rise to a new position to maintain a fixed differential pressure across it. Rate of flow is accurately measured

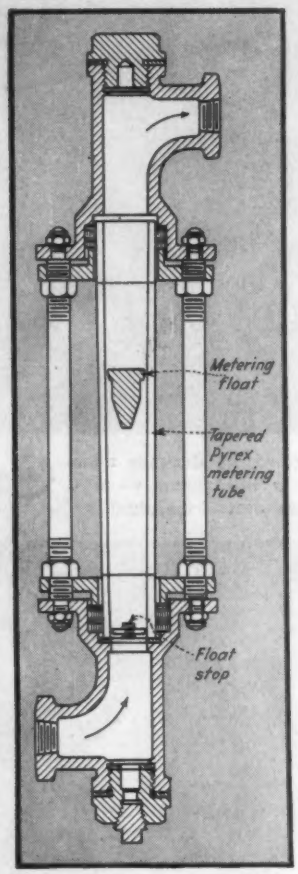


FIG. 1—Construction of a rotameter is shown in this sectional drawing. Position of the float depends on differential pressure which is automatically maintained constant by variations in the annular opening between float and tube as the float rises and falls. Flow-rate indication is linear

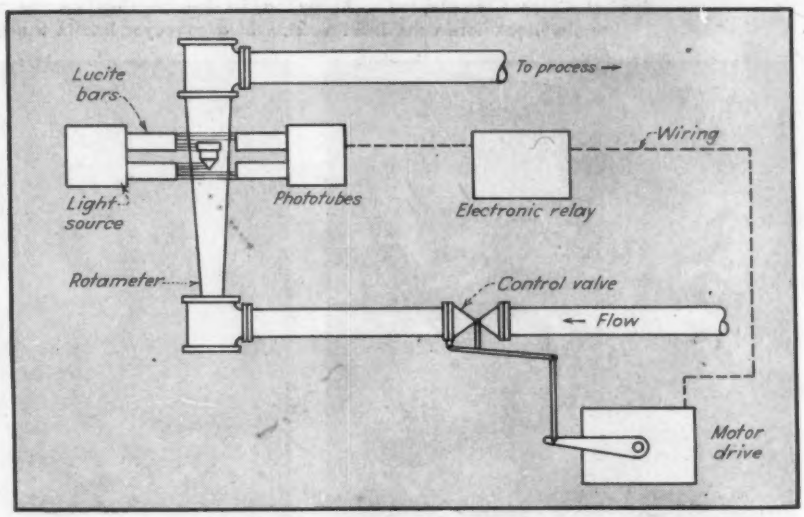
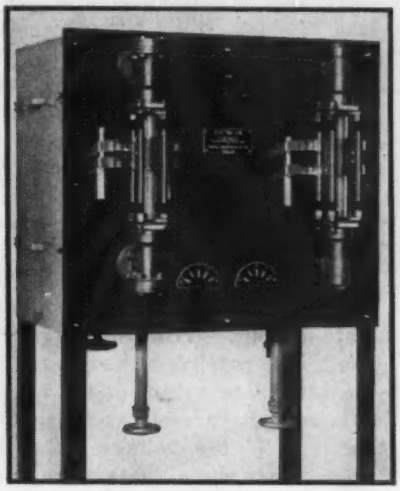
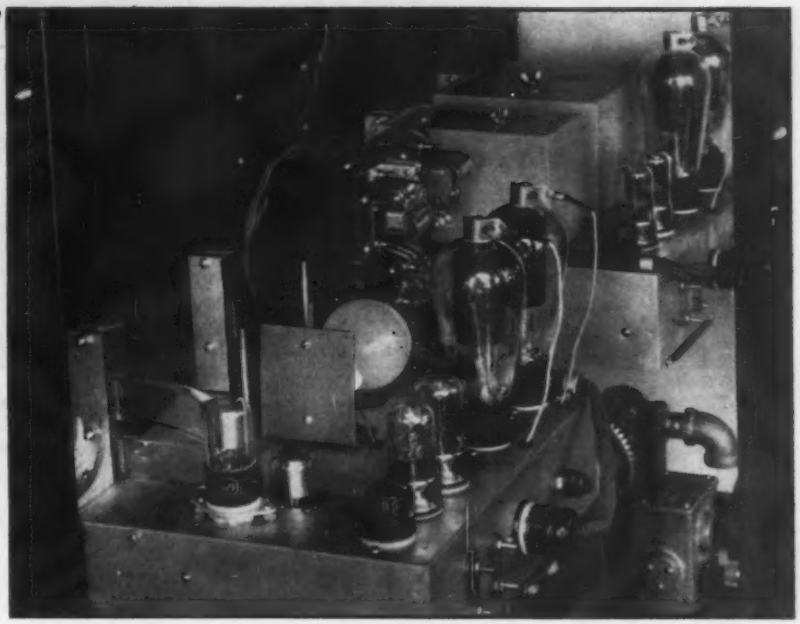


FIG. 2—Block diagram shows general operation of the flow-control unit. Provisions are incorporated to cancel out effects of line-voltage fluctuation and changes in color of the controlled fluid

OF FLUID FLOW

FIG. 3—The complete unit. Elevating handwheels are below and hand-automatic controls are on the front panel of the controller. Plastic light-transmission bars project through slots on either side of the rotameter tubes





Close-up of electronic control unit. . Covers have been removed from chassis in the foreground to reveal plastic bars which transmit light from the source to the rotameter glass and back to the phototubes

throughout the entire tube range due to the variable orifice (fixed differential) principle, and is not limited to a narrow range such as is the case in the fixed orifice type of flow meters.

Self-supervised Operation

For the past ten years, there has been a demand for automatic control applied to rotameters. Brooke Engineering Co. developed a control for this type of meter several years ago. The control operated on an induction principle such as is commonly used in other types of instruments. The float had an iron rod which hung down inside a center-tapped coil, mounted below the rotameter. This coil was electrically balanced against a similar, remote coil having an iron rod that could be positioned by hand.

Differences in balance of the two coils when the float moved out of its preset balance, were fed into an electronic relay which caused a motor to operate. This, in turn, opened or closed a valve to correct the flow rate. This type of control was not entirely satisfactory, due to the fact that its sensitivity was only plus or minus 1 percent, and phase shifts caused unstable operation if the control point was not near the center of the coil. Also, it could not be used on small sizes of rotameters, because the magnetic effect of the coil on the iron rod attached to the float was so great as to affect the sensitivity and accuracy of the rotameter.

About a year ago, a large refinery had a process in which they wished to maintain the flow rate of a fluid to ±½ percent and it was decided to use a fully compensated electronic relay, receiving its signals from phototubes. This system had been in successful operation for many years, measuring the smoke density of large industrial boilers and adusting the air supply to maintain a fixed smoke color at the boiler outlet.

For the rotameter application, it was decided to use two light beams, one shining across the top of the float, and the other across the bottom of the float. Each light beam was applied to a phototube, and the outputs of the phototube amplifiers were electrically balanced against each other to cancel out the effects of voltage changes and color deviation of the liquid.

If the float in the rotameter moved due to a change in flow, one phototube received more light and the other, less light. This unbalance caused a thyratron to operate a motor with compensation and with full torque at all times. This motor changed a control valve in the correct direction to restore the float to the set value within ±1 mm (0.0098 in.)

Disposition of Parts

Arrangement of the various pieces of equipment is shown in Fig. 2. The rotameter is mounted on a stand, in front of a panel as in Fig. 3. The electronic relay, with its light source common to both beams, and its phototubes, amplifiers, thyratrons, and allied equipment, is mounted behind the panel, as in Fig. 4. Lucite or Plexiglass bars are used to transmit the light

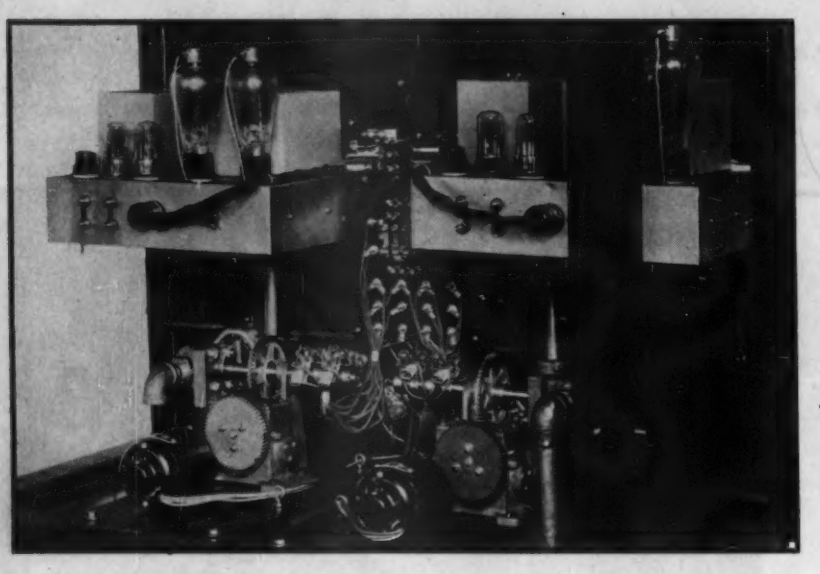


FIG. 4—In a rear view, motor drives and control valves appear below the electronic relays. Mercoid units mounted on the valve shafts include limit switches and extras which can be used to operate relays on terminal panel for automatic shut-down feature

out to the rotameter and back to the phototubes. The electronic relay is mounted on an elevator assembly which permits the operator to raise or lower the entire assembly to change the rotameter control setting. The unit is also supplied with a switch which permits the operator to remove the control from "automatic", and to raise or lower the flow to any desired value.

In addition to the compensated controlling action, described later, other features may be included in the electrical circuit when required. For example, automatic shut-down if any of the fluids in the process cease flowing or go beyond predetermined values, or if tubes or light source fail.

In most cases, a lock-in circuit must be employed to return the float within the range of the light beam if the characteristics of flow are such that an occasional surge in the fluid will raise or lower the float out of the light beam. This lock-in feature is most important. Essentially, it consists of electromagnetic relays which are actuated by the phototube amplifiers just before the float leaves the light beam. The lock-in feature discerns which way the float moved and operates the motor at full speed to return the float to the light beams where the thyratron can come into operation.

Referring to the circuit diagram in Fig. 5, when the output of V_3 goes beyond a predetermined limit, as set by R_{13}, a type 2050 thyratron in the lock-in circuit fires to energize a relay. When energized, this relay disconnects the cathode of an opposing 2050 so that it cannot operate, and puts a high positive voltage on the grid of the thyratron V_5 to run the motor at full speed. The lock-in circuit does not come into play until the float is about ready to leave the light beam.

The electronic relay employed converts impulses from a pair of phototubes into signals sufficiently large to run a reversible motor. Net movement of the motor is proportional to the signal and the motor has full torque at all times. The electronic relay provides electrical compensation by means of a circuit which varies the thyratron grid voltage by charging and discharging a capacitor at variable rates. Such compensation is similar in results to mechanical throttling and reset but is accomplished electrically without the use of relays, open contacts, or moving parts.

The light source is a 120 v bulb directed through two pieces of Lucite or Plexiglass to form two light beams shining across the rotameter. They are spaced so that when the float is in balance, one half of each light beam is blocked out and the other half of the beam passes through the fluid and metering tube to other bars of Lucite, and thence to the phototubes. The phototubes are of the high-vacuum type and are not appreciably affected by voltage changes.

Circuit Details

Direct-current bias for the phototubes, amplifiers, and thyratrons is furnished by the 6H6 rectifier. One half of the tube acts as an ordinary high-voltage half-wave rectifier, taking voltage drop across a load resistor, while the other half utilizes the drop across the tube, giving low voltage. Both plate outputs are filtered. Resistors R_1 and R_2 provide grid bias for V_3 and V_4 while C_1 and C_2 provide a-c grid-to-cathode return.

Phototubes V_1 and V_2 are so connected to their amplifiers V_3 and V_4 that the more light received by the phototubes, the lower the amplifier plate output. With this arrangement, it is possible to keep a nearly constant plate output of the amplifiers with a variable voltage. For instance, if the voltage falls, the light source dims, plate voltage of V_3 and V_4 drops, and the phototubes decrease the negative grid voltage of the amplifiers, thereby increasing plate output to approximately the same value as at the higher voltage. This will take care of line voltage changes in the order of ±5 v at 115 v. For greater changes of voltage the plate outputs of V_3 and V_4 will vary up or down together, but since these plate outputs are balanced against each other in T, it will not affect the control. With the amplifier plates balanced against each other, color changes of the liquid in the rotameter will also cancel out.

The plate of V_3 is connected to one half of the primary of push-pull transformer T, and the plate of V_4 is connected to the other half. Assuming the float is in neutral, light on V_1 equals light on V_2, plate outputs of V_3 and V_4 will be equal and cancel each other in the primary of T, and there will be no voltage developed in the secondary. If the float moves down from the neutral position, V_1 receives more light, and V_2 less light, therefore the grid of V_3 will become more negative, and the grid of V_4 less negative. The plate output of V_4 will become

greater and that of V_3 less, causing a voltage to be developed in the secondary of T. Since the primary voltage is pulsating half wave, an a-c voltage will be developed in the secondary.

A fixed, negative d-c bias of approximately 10 v is maintained on the grids of V_6 and V_7 by the rectifier when the float is in balance. If the float falls, as assumed above, the positive half of the a-c voltage developed in one half of the secondary of T reduces the negative grid voltage to approximately 2 v and V_7 fires to run the motor in a direction which changes the valve to restore the float to neutral. Note that the emission of tubes V_3 and V_4 is 180 deg out of phase with the emission of V_6 and V_7.

Anti-Hunt Compensation

It can readily be seen that if the motor were to run at full speed until the float reached its neutral position, hunting would occur. To introduce compensation C_3 is used in the following manner. When V_7 fires to run the motor, its plate becomes approximately 70 v negative. This negative voltage, in addition to running the the motor, charges C_3 through R_{11}, R_{10}, and R_9, to put a high negative voltage on the grid of V_7 to stop it from firing. Then, C_3 discharges through R_9, R_{10}, R_{11}, and the motor. Thyratron V_7 cannot fire again until C_3 discharges.

While the motor is not running, the float has a chance to come to rest. If its point of rest is not the neutral position, a signal from T will again cause the motor to run. If the float moves a great distance from neutral, a strong signal will be developed by T, and the motor will have to run a long time before C_3 is charged with a high enough voltage to overcome the effect of the secondary voltage of T. The motor will then have a long time delay. If the signal from T is weak, the motor will only be energized a short time to charge C_3 a small amount, and the time of delay will be short. In other words, the net rate of movement of the control valve will be proportional to the amount the float moves from neutral.

Capacitor and resistor values are so chosen that if the float moves a great distance, the motor will run at full speed without interruptions. As the float approaches neutral, the motor begins to step at a speed proportional to the distance from neutral. Capacitor-resistor combinations C_4-R_5 and C_5-R_7 also have a somewhat compensating effect but on a relatively small scale.

If the float had moved in a direction to fire V_6, a negative feedback voltage would have been induced in the motor field not being used. This induced voltage would be equal to the voltage running the motor, and would cause compensation as described above.

By this system the motor always has full torque, regardless of how close the float is to balance. This is extremely important for highly sensitive controls,—otherwise, should the valve stick, the torque delivered by the motor near the neutral point would not be sufficient to restore the float to its original balance point. This is often a limiting factor in many control devices.

Successful field operation of 64 of these units for several months has demonstrated that an extremely accurate control can be applied to devices where it is necessary to maintain a movable body in a fixed position. If greater sensitivity is required, concentrated light beams can be employed. By this method, a slight change in float movement will cause a greater signal change.

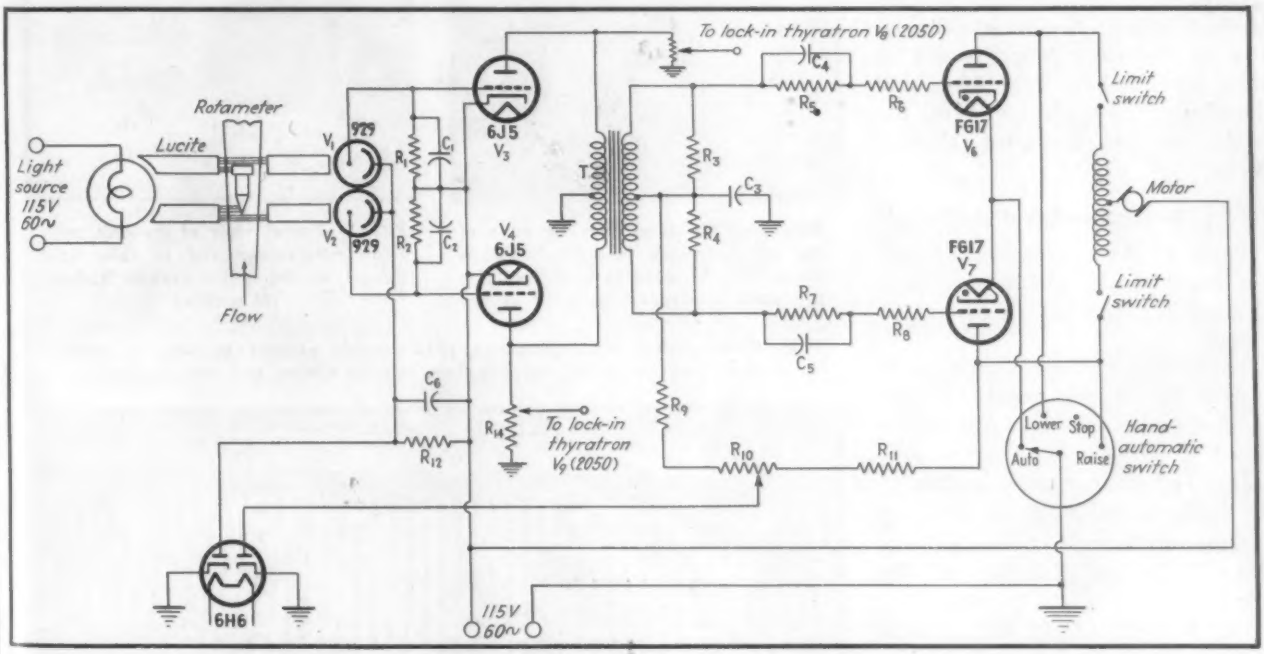


FIG. 5—Basic circuit of electronic relay includes a pair of FG17 thyratrons which can be replaced with FG57 type where a large motor is required for valve operation. Light source, shown as directly connected to the line, is sometimes put in series with the filaments of the rectifier and amplifier tubes for long operating life at reduced voltage

A Generator of Damped

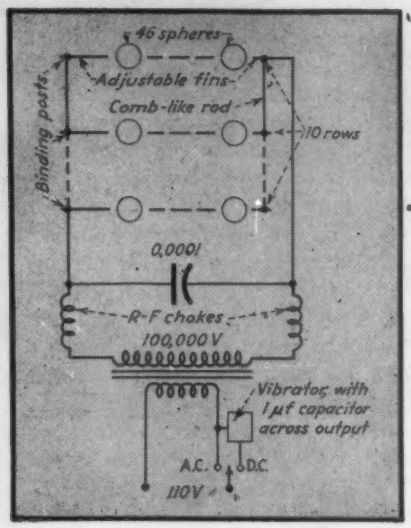


FIG. 1—Schematic of the generator

Spark discharges between 460 series-paralleled metallic spheres develop ½ watt of power at 7,000 Mc for the irradiation and stimulation of cells in biological studies

APPARATUS which has for its purpose the production of power at extremely high frequencies is usually associated with radio transmission but that described here was designed for use in the field of biology.

The generation of damped electromagnetic waves by means of spark discharges between metallic spheres dates back to the beginning of the century. A complete discussion of the early work is out of place here, and for hypotheses and theories on the subject we refer the reader to the appended bibliography.

Design Considerations

Some of the conclusions of earlier experiments which were kept in mind in designing the apparatus follow:

(a) When a metallic sphere is excited by electric sparks, highly damped trains of waves are generated.

(b) The approximate length of the fundamental wave is given by Thomson's formula $\lambda = 2\pi d/\sqrt{3}$, where d is the diameter of the sphere.

(c) The surface of the spheres must be and must remain highly polished, otherwise the discharge ceases to be oscillatory and becomes aperiodic.

(d) The energy of the electromagnetic waves generated by discharges between small spheres is of the order of 10^{-8} watt.

In order to utilize these conclusions in a practical way a large number of metallic spheres were fixed in a non-conducting frame, individually insulated, and at convenient terminals high voltage was applied. (The excitation of the spheres may be in parallel, in series or in series-parallel. The last disposition was preferable.)

Figure 1 shows a schematic arrangement of the circuit of the apparatus. It follows the theory of the spark-gap circuit once widely used in radiotelegraphy with damped waves, except for the fact that in this instance the spheres oscillate and radiate at the same time.

Description of Apparatus

The apparatus, shown in Fig. 2, is mounted on top of a cabinet in which a transformer is housed. Two

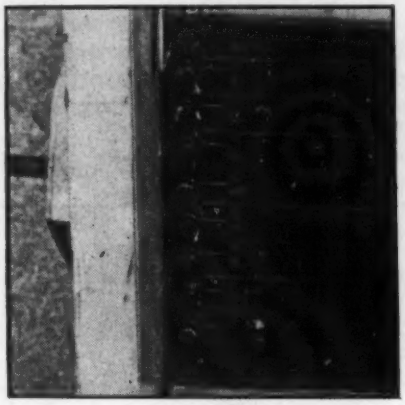


FIG. 3—Close-up of the left edge of the unit, showing how binding-posts which may be seen in a vertical line are used to permit adjustment of fins

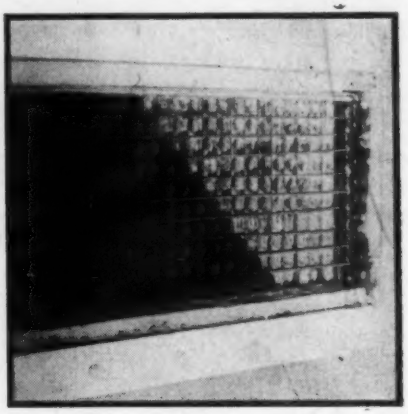
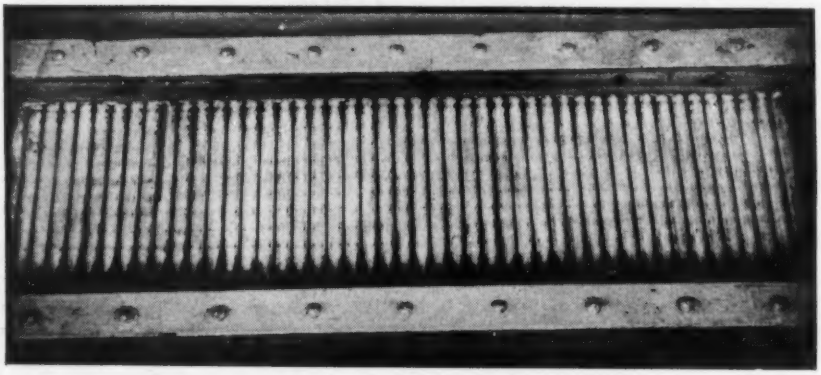


FIG. 5—Partial view of the unit, with some spheres removed to show how treated wooden strips provide horizontal spacing

FIG. 4—Paralleled round porcelain rods provide vertical grooves in which spheres may be placed, keeping them equally spaced and well insulated



Microwaves

By ANGELO MONTANI

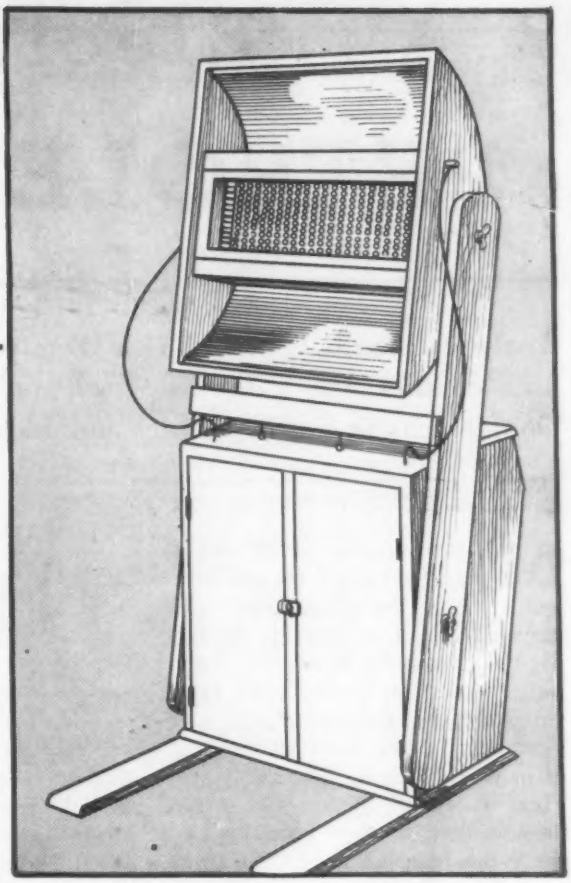


FIG. 2—The complete generator, consisting of a metallic-sphere spark-discharge unit and sheet-metal parabolic reflector to concentrate radiation. The cabinet on which the generator-radiator is mounted contains the high-voltage supply transformer

tiltable arms at the sides support a cylindric-parabolic reflector in which the radiating element is positioned.

The transformer used was taken from an old x-ray machine, and is rated at 100,000 v r.m.s., 500 w. Its terminals are connected through high-frequency chokes to two comb-like rods, each of which has ten adjustable "fins." The rods are equipped with binding-posts which permit adjustment of the fins. A set of binding-posts associated with one of these rods may be seen in a vertical line in Fig. 3.

Ten parallel rows of metallic spheres, each row having 46 spheres in series, constitute the generating and radiating element. The spheres are plain metallic balls such as those used in ball bearings, coated with platinum to prevent as long as possible rusting due to ozone produced by the sparks.

To obtain individual insulation of each sphere straight porcelain rods, 47 in all, were assembled against a flat wooden back to constitute a corrugated surface having 46 grooves, in each of which 10 spheres could be located in a vertical row, as shown in Fig. 4. With this disposition every sphere is horizontally spaced the same amount from the spheres to the left and right, which is important for the even distribution of sparks. Horizontally between each row of spheres long strips of treated wood, were inserted as shown in Fig. 5. To hold the 460 spheres against the porcelain rods a sheet of flat glass was provided to cover the entire surface of the radiant element.

The diameter of the spheres is 12 mm, and therefore the fundamental wavelength is approximately 43.4 mm. The power radiated by the whole system of 460 spheres at the fundamental wavelength is around ½ watt. (Assuming that the power of the harmonic waves decreases according to the square of the number of their natural sequence, the power of the tenth harmonic, or 4.3 mm, would be $\frac{1}{2}\ 10^{-2}$w, and the power of the one hundredth harmonic, or 0.43 mm. would be $\frac{1}{2}\ 10^{-4}$w.)

Purpose of Apparatus

The purpose of the apparatus was to make available in the biological field those radiations which fall between the centimeter waves and the heat rays, and to find out if such radiations might be of use in therapy.

Living things are made up of billions of individual "cells." These cells generally vary in size 10^{-1} cm and 10^{-4} cm, and are larger in vegetals and smaller in viruses. If we want to stimulate a cell we can do so by irradiating it with waves of the same order of magnitude, since under these conditions at least partial resonance may be expected.

Rays shorter than light excite the electrons of the atoms which form the cells, no matter where those electrons are. They may belong to a neuron or to a rock. On the other hand, short waves as used in diathermy cause in the tissue as a whole variable charges which, associated with the osmotic and capillary phenomena, alter the circulation of the liquids of the body. In both instances, the cellular metabolism that ensues is not a specific direct reaction of the cells to the radiation, but a derived effect. Cells in tissues represent a tridimensional grating, and with waves of proper dimensions it may be possible in the future to institute a new kind of spectroscopy of the living tissues and determine if there exists a kind of selective absorption peculiar to every type of cell.

Biological Use

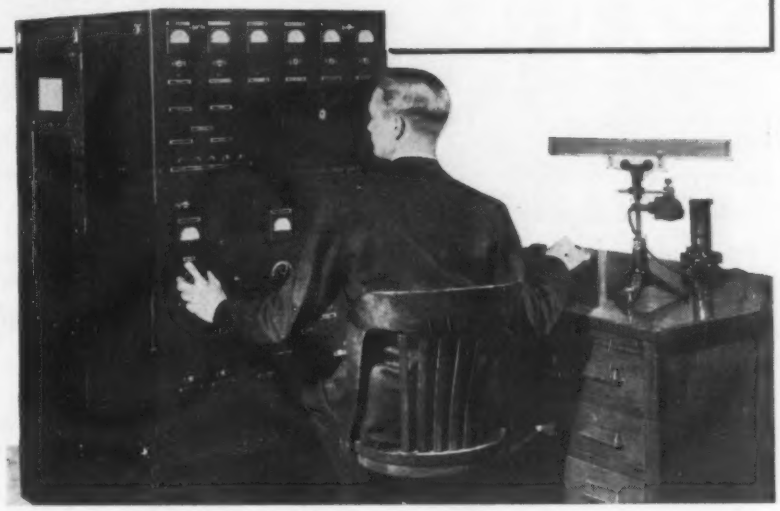
Between March and June, 1941, six biological experiments were performed with the above apparatus

(*Continued on page* 306)

SUMMARY OF ANALYTICAL METHODS USED IN PETROLEUM PRODUCTION AND RESEARCH

Method	Principal Use in Petroleum Industry	Remarks
Mass Spectrometry	Determination of low molecular weight hydrocarbons, such as analysis of the petroleum "gas cut."	Principally useful for mass-production analysis of routine gas samples. Instrument time is ¼ to ½ hour per sample but calculating time may require several hours. Extended range, high speed, pen and ink electronic recorders and automatic calculators are needed.
Infrared Absorption and Raman Spectrography	Determination of molecular components and identification of functional groups within molecules, such as analysis of aviation gasoline after fractional distillation or determination of mercaptans (S-H) in gasoline base stock.	Sample may be a gas, liquid or solid but must not contain more than about six molecular components if complete identification is desired. Most infrared samples must not contain water and Raman samples must not contain much fluorescent material. The electronics industry could greatly increase the usefulness of either method by supplying completely electronic detecting and recording circuits.
Ultraviolet Absorption Spectroscopy	Determination of aromatic and conjugated olefinic compounds, such as toluene in paraffinic base or butadiene for synthetic rubber manufacture.	Electronic detecting and recording systems are available in this field. A not-too-expensive instrument which automatically scans the entire spectrum is needed.
Emission Spectrography	Determination of metals and metalloids, such as analysis of catalysts for trace metals.	Good for rapid qualitative survey of sample or for quantitative determination of metals present in low concentration. The adaptation of electronic detecting and recording systems to replace the photographic emulsion would be very useful in most cases.
X-ray and Electron Diffraction	Determination of compound identity of crystalline materials; aids in the investigation of crystal structure and structure of colloidal or amorphous materials.	X-ray tubes and generating systems are designed to meet present requirements but electronic detection and recording is much needed in the x-ray diffraction field.
X-ray Microradiography	Tool to supplement useful metallurgical microscopy.	
Electron Micrography	Extends the range of ordinary microscopy so that smaller objects can be seen, and increases detail due to its great depth of focus.	A "reflecting" electron microscope seems to be the next step in this field.

is needed for the complete analysis. The application of the same principles to continuously recording units operating from plant streams is equally practicable. However, such equipment may often be quite complex and expensive in first cost.



Westinghouse mass spectrometer used for separating molecules of synthetic rubbers and oils according to their mass. Molecules of each mass in turn are made to enter a collector, and the resulting ion current is amplified and read with the galvanometer on the desk

The Frequency Spectrum

Most uniform oscillatory wave motion belongs to the electromagnetic spectrum which is shown schematically in Fig. 1. Sound, electrons, some nuclear rays, reciprocating mechanical motion, etc., are not electromagnetic in character and their wavelength or frequency regions can be shown only approximately. The radio spectrum is now well known up to about 1000 Mc,[2] but from here on to 1,000,000 Mc lies a relatively unexplored region which promises to be very important in the future.

The infrared region is somewhat arbitrarily said to begin at about 1,000,000 Mc or 300 microns, but the region from 300 to 30 microns is largely only of academic interest at present. The region from 30 microns (300,000 Angstroms) to 0.03 Angstrom is that in which the analytical methods described in this paper operate. In the shortest wavelengths are found hard x-rays and gamma rays. In the past two or three years gamma rays have been used to "log" oil wells and determine where oil-bearing strata might occur even though metal casing has already been set within the well.

With the advent of the cyclotron and similar atom smashers, nuclear rays have been used in numerous novel experiments involving radioactive "tracers". Atoms of a specific element can be "tagged" by making them artificially radioactive and then followed throughout the course of a reaction by following the progress of the radioactive atoms.

Cosmic rays, the most penetrating radiation known, are generated outside the earth's atmosphere. They have been found to discharge electroscopes after penetrating 18 feet of lead. Day and night we are subject to bombardment by cosmic rays.

The energy per quantum of electromagnetic radiation varies directly with the frequency, as shown in Table I. It is instructive to inspect briefly this energy variation, for this in part dictates the troubles encountered in detecting the radiation and dictates the energy available for photochemical reac-

Electronics in PETROLEUM PLANTS

Analytical methods involving a large portion of the electromagnetic spectrum are being used continuously today in petroleum production and research to identify molecules in complex gas or liquid samples and determine the exact concentration of each component

By
F. P. HOCHGESANG and C. H. SCHLESMAN

Socony-Vacuum Oil Co., Inc.
Research and Development Division
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MODERN AVIATION GASOLINE of the "100 plus" octane number variety, the all-purpose military lubricants required in today's highly stressed equipment, and pure chemicals produced from petroleum for the manufacture of synthetic rubber were all unheard of in World War I. The swift progress of petroleum research in the development of these products and the rapid translation of laboratory processes for their manufacture into vast commercial operations has spurred on the analytical chemist to new heights. Without the participation of the electronics industry, this progress would have been impossible.

In the past the simplest methods served to control the manufacture of gasoline and lubricating oils. Today, measurement of such simple properties as gravity, viscosity, and boiling range is not sufficient. Modern research demands far more explicit information. Usually the research chemist, and often the production engineer also, will not settle for anything less than knowing the complete composition in terms of the molecules present. When new methods developed for research purposes are applied to industrial control, our dependence upon stable amplifiers and electronic detectors and recorders becomes complete.

These modern radiation methods have again stressed the importance of the electromagnetic spectrum to the petroleum chemist. The regions most frequently employed in this field include the x-ray, ultraviolet, visible and infrared portions of the spectrum. Naturally the technique resembles that of the physicist more than that of the chemist. The chemist endeavors to make materials react with specific reagents to yield a unique product which will identify some component of the original sample and which can preferably be weighed or titrated to determine the concentration of the unknown component in the sample.

The physicist, on the other hand, usually makes measurements on the sample as received, often returning the sample still in its original condition. Such physical measurements yield new and direct information concerning the sample. These methods are frequently much more rapid than wet methods and only a small amount of the sample (sometimes less than a milligram)

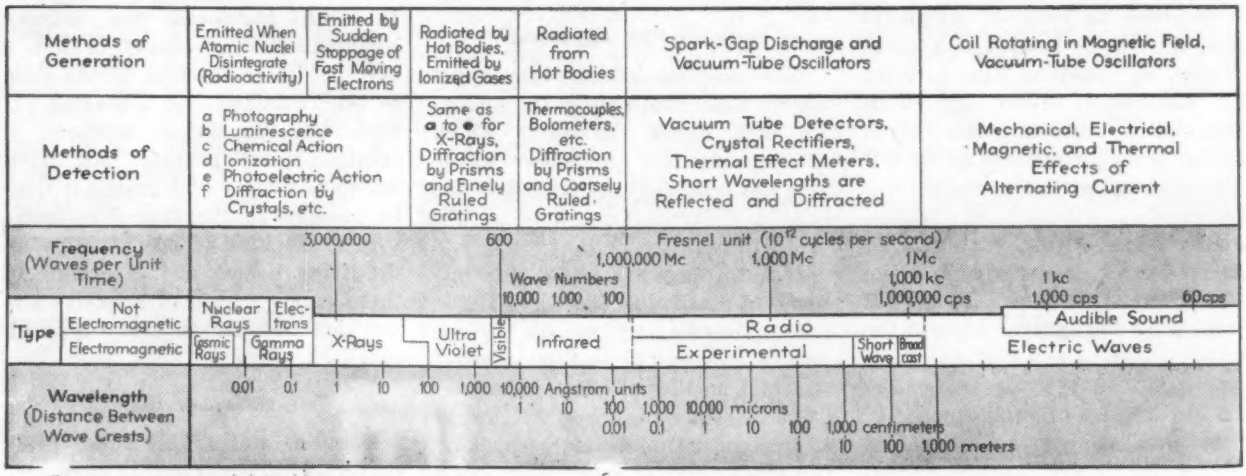


FIG. 1—The frequency spectrum, with upper boxes showing how various portions of the spectrum can be generated and detected for use in the petroleum analytical field

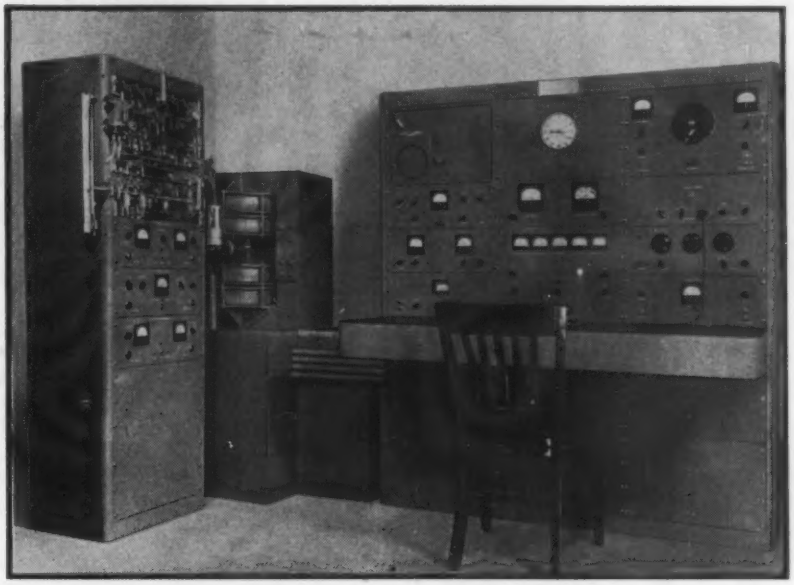
the mass spectra of known pure hydrocarbons, since the unknown mass spectrum can be considered as a summation or superposition of the mass spectra of all the components of the sample.

Infrared Absorption

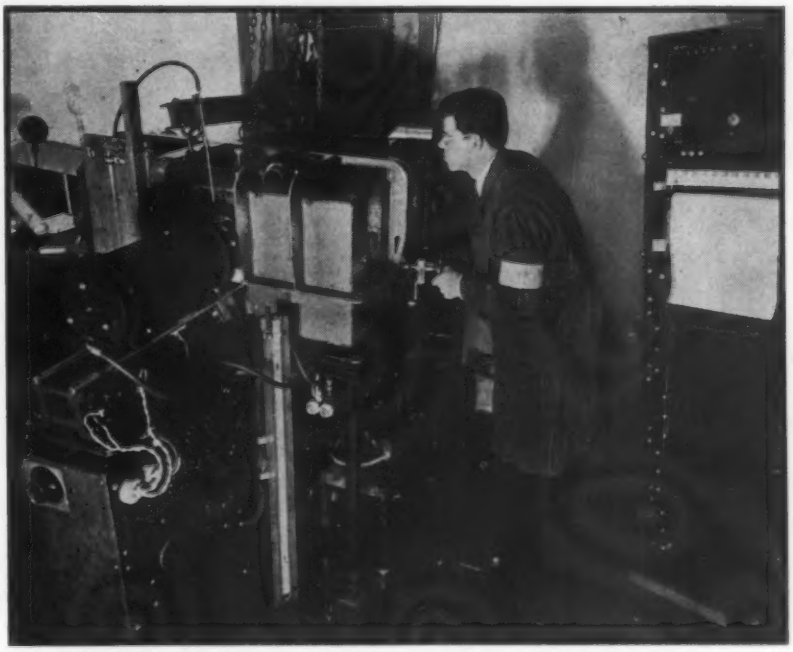
At the present time the mass spectrometer is used in the petroleum industry primarily to determine the molecular composition of complex mixtures of gaseous materials. Other spectroscopic methods are generally used to determine the composition of liquid or higher-molecular-weight samples and certain rather simple gas mixtures. For example, in high-octane aviation gasoline, it is well known that certain types of molecules are desirable and others undesirable. But many of both the good and bad molecules are very much alike in all their physical properties and often cannot be isolated by even the best fractional distillation techniques. Thus, n-heptane has zero octane number and isooctane has 100 octane number. Present-day aviation miracles would be impossible if much n-heptane was present in the fuel, but n-heptane and isooctane can be separated by distillation, if at all, only by very laborious procedures. Infrared spectroscopy[5, 9, 10] readily differentiates between these hydrocarbons, as is illustrated in Fig. 2.

All this is possible because the frequency of the 1-to-30 micron infrared region corresponds to the vibration frequencies of atoms or groups of atoms in hydrocarbon molecules. As long as any molecule is not at absolute zero, the atoms within the molecule are constantly oscillating about their positions of equilibrium. For example, a hydrogen atom vibrates against a carbon atom in aliphatic hydrocarbons with a frequency corresponding to a wavelength of 3.4 microns. This vibration is a simple stretching vibration wherein the frequency of oscillation is, to a first approximation, determined by the mass of the vibrating atoms and the valence forces which bind them together. A physical analogy is the resonance vibration of two spheres of given weights connected by a spring. If the tension of the spring is increased the resonance vibration will occur at a faster frequency and this happens in molecules also. In ethane, $H_3C\text{-}CH_3$, the carbon atoms are connected by a single bond and vibrate against each other at 993 cm^{-1}. In ethylene, $H_2C{=}CH_2$, the carbons are connected by a double bond or stronger spring. The vibration is more rapid, at a frequency of 1623 cm^{-1}. [1 $cm^{-1} = 1/\lambda$ (cm).]

The vibrations just described are all simple stretching vibrations. Atoms also may vibrate in such fashion that angular motion occurs and such vibrations are called deformation or bending vibrations.



In this mass spectrometer made by Consolidated Engineering Corp., several cabinets full of electronic equipment are needed to provide an automatic record showing how many ions of each mass are present in a gas. From left to right, the cabinets contain gas introduction systems and vacuum gages; the magnet, with the mass spectrometer tube between the pole pieces; and the power supplies, ion current amplifier, recording oscillograph and automatic mass scanning device



Infrared spectrograph used in Socony-Vacuum Laboratories. The spectrograph proper is in a metal housing to permit evacuation for removal of water vapor and carbon dioxide. On the rack at the right is the pen and ink recorder that traces out the spectrum of the material being analyzed

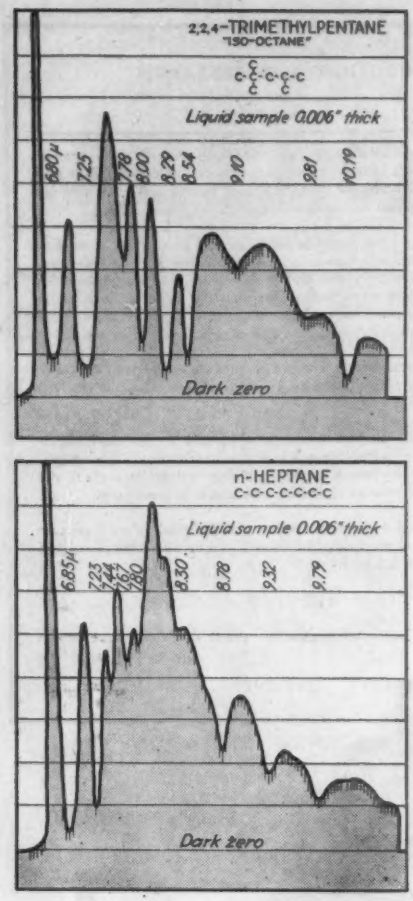


FIG. 2—Infrared absorption spectra obtained automatically with an infrared spectrograph covering the wavelength region from 7 to 10 microns, for two hydrocarbons that are difficult to separate by distillation. Characteristic absorption peaks provide positive identification of gas or liquid samples

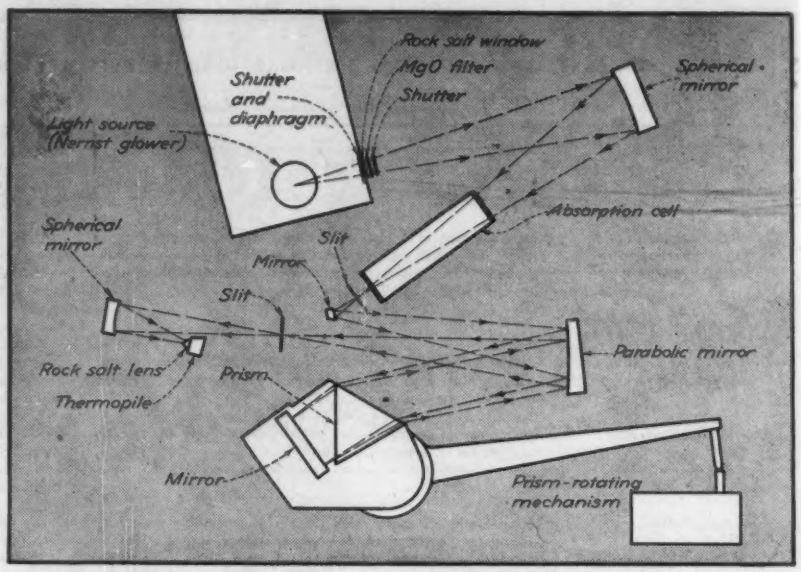


FIG. 3—Optical arrangement of infrared spectrophotometer made by National Technical Laboratories. The gaseous sample to be analyzed is placed in the absorption cell. The thermopile (or thermocouple) output is read on a sensitive galvanometer mounted in a draft and vibration-proof housing

tion. Thus, the short wavelength radiation such as x-rays and ultraviolet rays readily enters into photochemical reactions. Ultraviolet and visible radiation readily activates photoelectric surfaces. The long-wavelength infrared and radio waves in general cannot enter into photochemical reactions because the energy per quantum of radiation is too small. Radiation of wavelength longer than about 2 microns cannot expel photoelectrons from photoactive surfaces which would be stable at room temperature.

Mass Spectrometry

The newest of the new analytical tools applied to petroleum problems is the mass spectrometer. Commercial instruments are capable of routine refinery control work to provide accurate petroleum gas analyses in amazingly short times on samples so small that their size is dictated by sample handling techniques in collecting and transporting the sample rather than the amount required for analysis. Mass spectrometry finds its greatest usefulness within the petroleum industry[3, 4] as a method that replaces tedious low-temperature fractional distillation and accompanying techniques for the control of refinery gaseous streams.

In the rapid spectrometric methods devised to analyze the petroleum "gas cut", the instrument time required is about ¼ to ½ hour per sample and results from the data obtained can be calculated in from a few minutes to several hours depending upon the problem. This method soon proves its value when one realizes that other methods require from 4 hours to several days to do the same job. Usually the results from the mass spectrometer are more accurate and the method is less subject to operator errors.

The mass spectrometer is so named from certain similarities it possesses to an optical spectrometer. The latter separates light into its various component wavelengths by the dispersion obtained in passing light through prisms or gratings. The mass spectrometer separates gas molecules according to their mass by ionizing the gas, accelerating these ions, and deflecting them in a magnetic field. Gas from the sample is made to pass through several tiny orifices, so that a constant flow occurs into the spectrometer tube in which a high vacuum is maintained by continuous pumping. Electrons from a heated filament are accelerated by passing through a potential gradient and fall on the entering gas stream, causing ionization and dissociation of some of the gas molecules. The molecules not thus excited are drawn out of the system by the exhaust pump. The ions and ion fragments thus formed are urged toward a slit in a plate by a small potential difference and then are accelerated to very high velocity by an electrode arrangement similar to that in an electron gun. The resulting high-velocity ions are directed into a magnetic field. Only certain ions having the correct mass-to-charge ratio will travel through the center of the analyzer tube and ultimately lose their charge to the ion collector from whence their current is amplified and measured.

By variation of the accelerating potential and/or the magnetic field, such an instrument can be made to determine the relative abundance of various weight ions. This data can be converted to the relative abundance of the various molecules in the initial sample by comparing the unknown mass spectrum with

are difficult to identify in this region. Even the water vapor and carbon dioxide in the air must be eliminated from the optical path through the instrument or a correction made. The optical arrangement of one such instrument is shown in Fig. 3.

The radiation involved in spectroscopy is of very low inherent energy, as shown in Table I. It cannot be photographed at wavelengths longer than 12,000 A or 1.2 microns, and will not actuate photo electric cells above about 1.7 microns. It can only be detected by tiny thermocouples, bolometers, radiometers, etc. Such instruments must detect temperature changes with a limit of error equal to, or less than, 0.00005 deg C. The most commonly used detector is the thermocouple. A microvolt output of the thermocouple must develop about full-scale deflection on the recording instrument used. Since the usual resistance is only about 15 ohms and the period about 1 second, electronic amplification is difficult. Sensitive galvanometers with their accompanying vibration troubles must be relied upon. The authors know of just one case where, in the past few months, a thermocouple has been made with sufficiently small mass so that its period is faster than 1 second and electronic amplification of the thermocouple output has become possible. The spectrograph in use in the Socony-Vacuum Laboratories uses a bolometer as a detector. Electronic amplification is used and results to date indicate that this combination marks an important step forward.

Ultraviolet Absorption Spectroscopy

The readily accessible ultraviolet region of the spectrum from 2,000 A up to the visible region also displays phenomena related to the structure of molecules. Molecules which contain resonating groups, such as diolefins which contain conjugated unsaturated carbon groups, exhibit selective absorption of ultraviolet light.

Of particular interest to the petroleum industry, aromatic hydrocarbons[11] and drying oils and resins[12] yield characteristic ultraviolet absorption spectra by means of which such molecules can be identified. Saturated hydrocarbons do not absorb appreciably in this region. Thus, the identity and concentration of some aromatic compounds (those which may be present in gasoline) can be determined without separation from the paraffinic hydrocarbons.

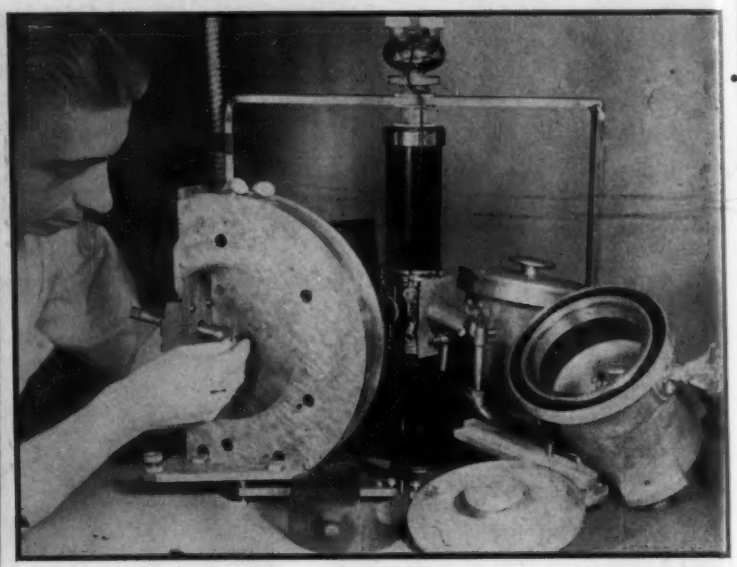
An analysis has been reported wherein straight-run or saturated naphtha is split into five fractions over the range of 125–150 deg C and these fractions analyzed for ethylbenzene and the three xylenes with an accuracy better than that of any other available procedure. More

(*Continued on page* 308)

In this emission spectrograph, the samples to be analyzed are burned in an electric arc or spark in the hood at the right. The light emitted is broken into its spectrum by a quartz prism, and the spectrum is recorded on film

At the right are four evacuable powder cameras in position around the x-ray tube of an x-ray diffraction unit. High-voltage equipment is under the table, enclosed by metal screening. The operator is adjusting the intensity of the x-ray beam. This unit was built in Socony-Vacuum Laboratories about six years ago, but complete and versatile commercial equipment is now available

This Leeds and Northrup recording microphotometer can be used to measure the optional density of each spectral line on a photographic plate produced by an emission spectrograph



Operator is placing a sample on a spindle in the center of a large-diameter cylindrical x-ray diffraction camera. Smaller cameras, a pinhole camera and a Philips-Metalix x-ray tube used as a source of radiation for these cameras can also be seen

For example, an H-C-H or CH_2 group in aliphatic hydro-carbons has a strong deformation vibration at 1,460 cm^{-1}. Atomic groups may rotate with respect to one another, thus yielding still another type of motion having a characteristic frequency. Many combinations of the above types occur to yield combination frequencies. Any molecular vibration which is accompanied by a change of dipole moment is "infrared active" and will absorb, by resonance, radiation corresponding to the frequency of vibration.

Raman Spectroscopy

Raman spectroscopy[5, 6] supplies essentially the same information concerning molecular composition as infrared absorption studies but accomplishes the task in a different manner. In Raman spectrography, light of characteristic and usually visible wavelength, such as that from a mercury discharge tube, is allowed to illuminate the sample. Light originating in the sample at a direction perpendicular to the incident beam is dispersed in a large-aperture spectrograph and the resulting spectrum photographed and examined. This scattered and/or re-emitted light coming from the sample contains light of frequencies corresponding to that of the incident beam plus or minus the frequencies of various vibrating groups within the sample, and thus can be used to identify the parent molecules. Samples for Raman investigation must be well fractionated just as with infrared.

The photographic process complicates quantitative interpretation of Raman spectra, and a direct-reading, automatic-recording detecting system for the visible light emanating from a Raman spectrograph would greatly enhance its industrial usefulness. Multiplier phototubes have already been successfully applied to this problem[7].

TABLE I. Quantum Energy of Some Electromagnetic Radiations

WAVELENGTH		APPROXIMATE COLOR	ENERGY		
Angstroms	Microns		per quantum (ergs)	per einstein* (kilo-cal.)	relative
300,000	30	Infrared	0.066 x 10^{-12}	0.95	0.33
100,000	10	Vibration infrared	0.196 "	2.85	1
10,000	1	Photographic infrared	1.96 "	28.5	10
7,000	0.7	Red	2.81 "	40.7	14.3
6,200	0.62	Orange	3.17 "	45.9	16.1
5,800	0.58	Yellow	3.39 "	49.1	17.2
5,300	0.53	Green	3.71 "	53.8	18.9
4,700	0.47	Blue	4.18 "	60.5	21.3
4,200	0.42	Violet	4.68 "	67.8	23.8
3,000	0.30	Ultraviolet	6.55 "	94.8	33.3
1,000		Vacuum Ultraviolet	19.6 "	285	100
100		Long X-rays	196 "	2,850	1,000
1		X-rays	19,600 "	285,000	100,000
0.1		Gamma Rays	196,000 "	2,850,000	1,000,000

* The einstein is similar to the faraday or chemical equivalent of electrical energy.

Experimental Difficulties with Infrared Spectroscopy

Infrared spectroscopy is used at present in the petroleum industry to a much greater extent than Raman, even though the experimental difficulties in infrared work constitute a formidable list. To mention a few, ordinary optical materials will not transmit infrared radiation in the wavelength region used and prisms and windows of sodium chloride, potassium bromide and lithium fluoride are used in conjunction with front-surfaced mirrors.

These are now available in large perfect crystals of synthetic manufacture but the chloride and bromide are readily attacked by water vapor and must be handled accordingly in use. Gratings are not useful for general survey work because overlapping orders of spectra

INFLUENCE OF FEEDBACK O

Analysis of the use of negative feedback to reduce source impedance in amplifier stages and transmission lines, as required in video design and other applications where high-frequency response must be improved or loudspeaker "hangover" must be eliminated

By RICHARD W. CRANE

INVERSE FEEDBACK is widely used in amplifiers today to stabilize gain, improve frequency response, and reduce distortion. One other extremely valuable feature of negative feedback is the apparent reduction of source impedance it may cause; this is not only important in itself, but may also serve as a basis for analyzing all the other features of feedback.

Impedance Consideration

Let us then derive a formula for the variation in source impedance with feedback. The gain of a feedback amplifier is

$$\alpha' = \frac{\alpha}{1 - \alpha\beta} \qquad (1)$$

where α' = gain with feedback, α = gain without feedback, and β = ratio of feedback voltage to output voltage, or the fraction of output voltage fed back (negative for degeneration).

As the load impedance approaches infinity the equation

$$\alpha = \frac{-\mu Z_L}{Z_L + R_P} \qquad (2)$$

approaches the value $\alpha = -\mu$, and α' approaches the value $-\mu/(1 + \mu\beta)$, where μ = amplification factor of the tube, R_P = plate resistance of the tube, and Z_L = load impedance.

In Fig. 1, which is the equivalent circuit of an amplifier stage, one method of finding the source impedance would be to connect a load of such value that the voltage at T_1T_2 measured exactly half the value it would have if the load impedance were infinite, in which case Z_L would equal R_P. Practically, this would mean choosing a value of Z_L such that $\alpha = -\mu/2$. The same reasoning holds true for an amplifier with feedback, where $R_P = Z_L$ when

$$\alpha' = \tfrac{1}{2}\left(\frac{-\mu}{1 + \mu\beta}\right) \qquad (3)$$

Substituting Eq. (2) in Eq. (1),

$$\alpha' = \frac{\dfrac{-\mu Z_L}{Z_L + R_P}}{1 + \dfrac{\beta\mu Z_L}{Z_L + R_P}} \qquad (4)$$

To find the apparent plate impedance we need only substitute the value of α' given by Eq. (3) in Eq. (4) and solve for Z_L, which will be the value of load impedance required to make α' equal one half its maximum value, and will therefore also be the source impedance of the amplifier:

$$\tfrac{1}{2}\left(\frac{-\mu}{1 + \mu\beta}\right) = \frac{\dfrac{-\mu Z_L}{Z_L + R_P}}{1 + \dfrac{\beta\mu Z_L}{Z_L + R_P}}$$

Solving for Z_L,

$$Z_L = R_P' = \frac{R_P}{1 + \mu\beta} \qquad (5)$$

(In this equation μ must be negative. Strictly speaking, it should always be, because of the 180 deg phase reversal in an amplifier stage).

From this formula it can be seen that negative feedback in effect reduces the plate resistance of a tube, and in a practical case can make a pentode or beam power tube have a source impedance as low as that of a triode, or lower.

It is well known that pentode and beam power output stages have poor frequency response and appreciable distortion. These defects are manifested mainly in two ways.

Defects of Pentode and Beam Tubes

First, the speaker tends to have "hangover"; that is, the cone and voice coil assembly tends to vibrate at its own natural period when a transient or a steep wave front signal is applied, and the amplifier's output will be far above normal when a signal is applied whose frequency is equal or close to the mechanical resonant frequency of the speaker. This does not occur in a triode because the low-impedance source shunts the speaker's counter emf and effectively damps the vibration. A pentode or beam tube with enough feedback to approximate a triode's plate resistance will behave similarly.

The second effect is a response which rises with increasing frequency; this happens because the primary inductance of the output transformer presents an appreciable (and, of course, varying) load to the tube throughout the audio spectrum. In a triode stage the

FIG. 1—Equivalent circuit of an amplifier stage connected to a load

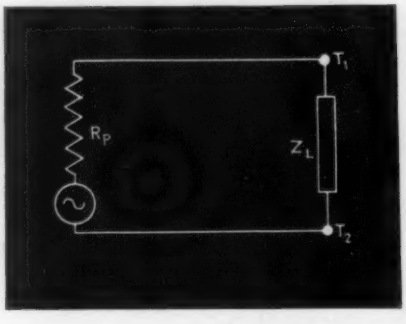
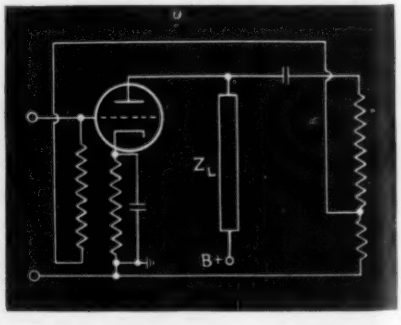


FIG. 2—Voltage feedback circuit using a portion of the output voltage



ON SOURCE IMPEDANCE

transformer primary's inductive reactance is high compared to the tube's plate resistance except at the very lowest audio frequencies, and thus a fairly uniform response is obtained. As in the first case, feedback will enable a beam power or pentode tube to give similar performance.

Pentode voltage amplifiers can use feedback advantageously also, for it will lessen the effect of the input capacitance of the next tube and therefore improve the high-frequency response.

In general, it may be said that inverse feedback will improve the action of any tetrode or pentode amplifier whose load contains shunt reactive components.

Current Feedback Circuit

The foregoing discussion and derivation assume that β is constant regardless of changes in load impedance. This is true in the circuit of Fig. 2 or in any circuit where a portion of the output voltage is fed back. If we consider Fig. 3, however, we see a network in which a voltage is fed back which depends on the output current rather than the output voltage, and β is not constant but depends on Z_L. In this case β is determined by the ratio of the voltage drop across R_F to the voltage drop across Z_L. Therefore,

$$\beta = -\frac{i_P R_F}{i_P Z_L} = -\frac{R_F}{Z_L} \qquad (6)$$

In the circuit of Fig. 3, Eq. (2) becomes

$$\alpha = \frac{-\mu Z_L}{Z_L + R_F + R_P} \qquad (7)$$

and Eq. (4) becomes

$$\alpha = \frac{\dfrac{-\mu Z_L}{Z_L + R_F + R_P}}{1 + \dfrac{\beta \mu Z_L}{Z_L + R_F + R_P}} \qquad (8)$$

Substituting Eq. (6) in Eq. (8),

$$\alpha' = \frac{\dfrac{-\mu Z_L}{Z_L + R_F + R_P}}{1 - \dfrac{\mu R_F}{Z_L + R_F + R_P}}$$

Simplifying,

$$\alpha' = \frac{-\mu Z_L}{Z_L + R_P + (1 - \mu) R_F} \qquad (9)$$

Eq. (9) is identical with Eq. (2) except that α becomes α' and R_P becomes $[R_P + (1 - \mu) R_F]$. Our formula for apparent source impedance, considering μ negative as in Eq. (5), is

$$R'_P = R_P + (1 - \mu) R_F \qquad (10)$$

Thus in Fig. 3 or in any current feedback circuit, the tube's plate resistance is increased, and hence the output current tends to be stabilized, rather than the output voltage as in a voltage feedback circuit. Current feedback will not improve frequency response because if the load impedance varies with frequency β will also vary. For this type of feedback Eq. (1) becomes

$$\alpha' = \frac{\alpha}{1 + \dfrac{\alpha R_F}{Z_L}}$$

Current feedback is especially undesirable in power amplifiers for it tends to stabilize the output transformer's magnetizing current (i.e., make it sinusoidal), and thus produce a distorted output voltage.

Phase Inverter

The circuit in Fig. 4 represents a phase inverter network which utilizes feedback. Half the load resistance is in the plate circuit and the other half is in the cathode circuit, hence $\beta = -0.50$, $\alpha' = 2$ and $E_1 = -E_2$. This is, apparently, quite a good circuit for phase inversion; however, if we examine it in the light of the above discussion we can see an interesting problem. Looking back into the plate circuit we see a current feedback arrangement and a high-impedance source. On the other hand, the cathode load sees a voltage feedback circuit and a low-impedance source; thus it is apparent that the network will not give perfect phase inversion. A pentode would give especially poor results in such a circuit; however, the writer has obtained satisfactory results by using a low-μ triode with a low value of load resistance in such an arrangement.

Load in Cathode Circuit

Figure 5 is an interesting application of voltage feedback. The entire load is placed in the cathode circuit, so that $\beta = -1$, and from Eq. (5) R'_P very nearly equals R_P/μ or $1/G_M$. This circuit is useful where a very low source impedance is required, as for instance in certain video applications.

Conclusions

A significant fact to remember is that by using Eq. (5) and the circuits in Fig. 2 and Fig. 5 it is possible to match any tube to any load whose value is equal to or greater than $1/G_M$.

Inverse feedback reduces the gain of an amplifier of course, but this is no problem with present-day high-gain tubes, and the advantages of feedback offset this.

FIG. 3—Current feedback circuit using drop in cathode resistor

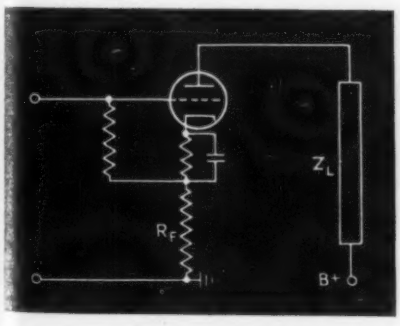


FIG. 4—Circuit using feedback for phase inversion

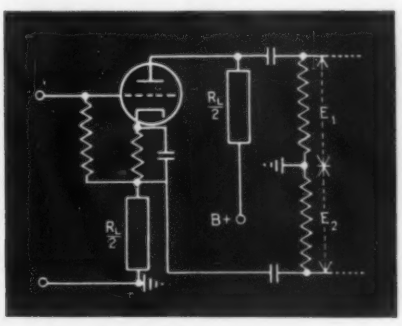
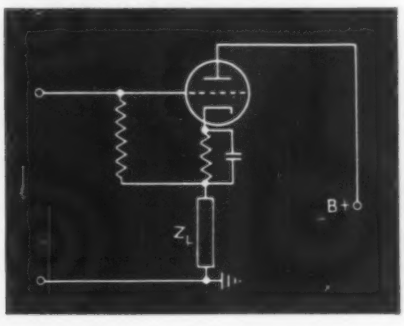


FIG. 5—Cathode-loaded circuit with extremely low source impedance



Gas-Filled and V

Significant features are reviewed. These include low power loss, high breakdown voltage, space economy, stable dielectric constant, low temperature coefficient, high efficiency, good dielectric strength, and self-healing capabilities

Vacuum capacitors for 7500 peak voltage in 25 and 50 $\mu\mu$f sizes are supplied by General Electric Co. in the style at the left. Applications for the same capacitances at 16,000 peak volts are filled by the type at the right. Size comparisons with air capacitors give these units ten-to-one advantage for the same voltage rating

By HERBERT B. MICHAELSON
New York, N. Y.

IN MODERN RADIO and electronic apparatus, the conventional air capacitor is often suitable because its power losses are ordinarily so small as to be almost unmeasurable. However, both air and solid dielectrics have certain limitations, many of which can be obviated by the use of vacuum or gas-filled capacitors.

Vacuum Capacitors

Electrodes of vacuum capacitors are coaxial cyinders or bell-shaped plates sealed in evacuated glass envelopes, with leads brought out to metal end-cups. Capacitive edge effects are minimized by the coaxial construction, and, because electrostatic field strength has an essentially constant value at all points on the polished surfaces, a uniformly high breakdown voltage is achieved. Electrode spacing is of the order of 0.06 in., height of the cylindrical plate being less than an inch in a typical 50-$\mu\mu$f unit.

Metal must be a type that will not give up occluded gases and thus reduce the high vacuum. Tantalum has been used successfully by some manufacturers.

Air pressure within a typical vacuum capacitor is as low as can be obtained by pumping alone—or less than one micron of mercury. When flashover occurs, the plates, as described by George H. Floyd, General Electric Co., have a tendency to clean up, rather than to corrode or become pitted, because of the extreme scarcity of oxygen and other gases within the envelope. Fixed vacuum capacitors are available in sizes ranging from 3 to 250 $\mu\mu$f, with ratings varying from 5,000 v to 35,000 v peak. In practice, these ratings are extended where necessary by use of series-parallel combinations, forming an unusually compact capacitor bank for very high voltages. A typical 50-$\mu\mu$f unit has an overall length of 3-5/16 in., a diameter of 1-§ in., and a rating of 7,500 v. peak. Manufacturers of vacuum capacitors include: Eitel-McCullough, General Electric, General Electronics, and Jennings Radio Mfg.

Electrical Characteristics

Breakdown of a gaseous dielectric does not occur until the potential is great enough to cause collision ionization. The breakdown rating of an air gap within a glass envelope decreases, as air is exhausted, until a certain barometric pressure is reached. Down to this point, the mean free electron path is being lengthened, and the mobility of gaseous ions is increasing, aiding ionization.[1] After this point, further exhaustion of air results in a sharp increase of dielectric strength because ionization is now actually hampered by a scarcity of gas molecules. Sparking potential then depends mostly upon the number of gas particles between the plates[2].

Figure 1 gives typical voltage breakdown curves of plane electrodes, spaced at 1 and 2 cm, at various air pressures. Voltage breakdown in a uniform field is actually a function of the product of gas pressure and plate spacing, as given by Paschen's Law. However, this does not apply accu-

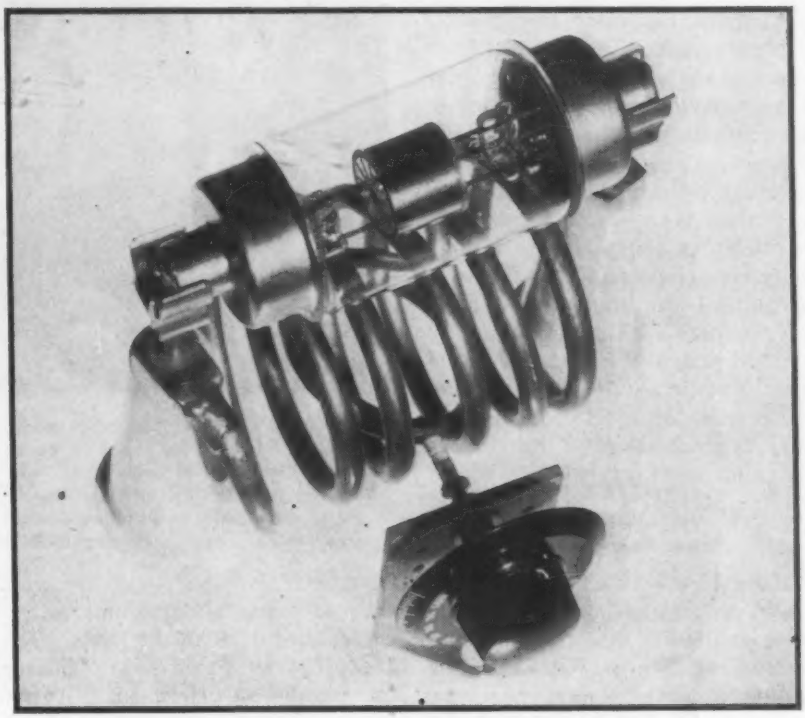
Vacuum Capacitors

rately at very low or at very high pressures, where sparking potential depends to a considerable extent on surface condition and material of the electrodes.[3]

Minimum sparking-potential for any spacing in air is 342 v. In other words, for any given electrode spacing, (1 cm., for example) breakdown voltage will decrease as air pressure is reduced, down to a certain point. When a breakdown voltage as low as 342 is reached; and air pressure is further decreased, breakdown voltage will now start to increase, as shown in Fig. 1. The same is true for any electrode spacing, whether it be 1 mm, 10 cm, or 100 cm. The shape and position of the curve for different spacings will, of course, vary, but the lowest point of any curve will be exactly 342 v., where the gas between electrodes is air. Minimum sparking potential for other gases is not identical with that of air.

Boiled down to its essential fact, popular theory holds that a gas will ionize most readily when a certain optimum number of gas molecules exists between the electrodes. When this number is decreased, electrons do not pass from one electrode to the other readily, because of the scarcity of gas particles which could form an ionized path. On the other hand, when there is a large number of molecules, the electrons collide too frequently with them, losing most of their speed, and thus never reaching the opposite plate.

Obviously, from Fig. 1, very high break-down gradients can be reached with short electrode spacings and low atmospheric pressures. Millikan suceeded in obtaining breakdown ratings as high as 600,000 v. per mm in high vacuum. Air at normal pressure (76 cm of mercury) and 25 deg. C is rated at about 3,000 v. per mm., (Townsend) assuming a uniform electrostatic field. Certain grades of good mica, 3 mm thick, are rated at 58,000 v. per mm.[4] and polymerized styrene of the same thickness, about 2,400 v. per mm.



Tank circuit utilizes vacuum capacitor of Eitel-McCullough design. Internal construction features rigidity for the maintenance of stable capacitance values

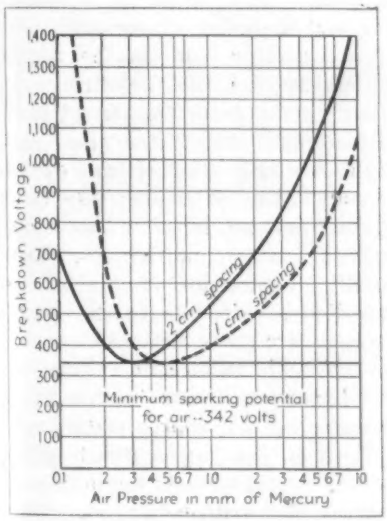


FIG. 1. Curves show that sparking in air under various pressures, about parallel-plates, always takes place at 342 v.

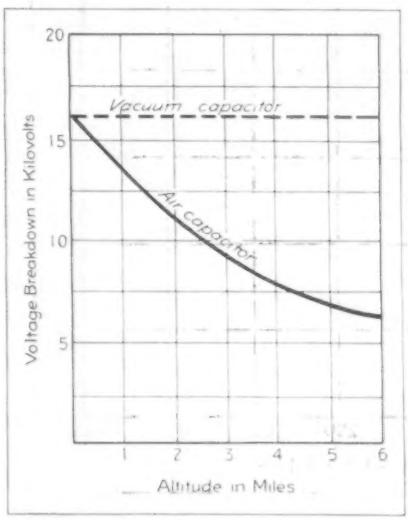


FIG. 2. Altitude-voltage breakdown curves for vacuum and air capacitors demonstrate the former's advantage for use in aircraft

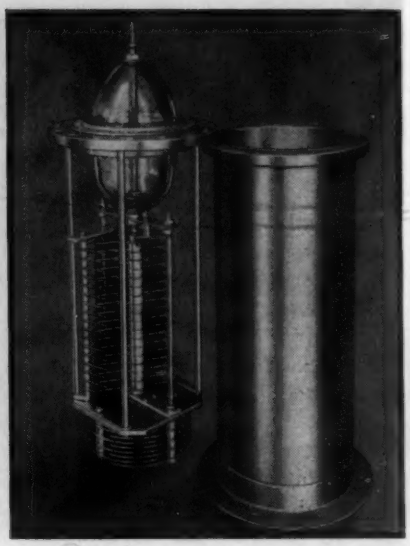
Altitude Reduces Breakdown Voltage

As shown in Fig. 2, flashover ratings of air capacitors decrease with a rise in altitude. Also, an increase of humidity causes a thin film of moisture to form on the plates and spacing insulators of a typical air capacitor, thus appreciably affecting the flash-over voltage. This humidity-voltage variation may be as much as 7 percent in practice.[5] Corona losses, too, become an important consideration as the decreasing breakdown rating approaches applied voltage in an

aircraft capacitor. Absence of internal corona and stability of voltage ratings make vacuum capacitors well suited to aircraft applications.

Where a capacitor has a solid dielectric such as mica, breakdown potential varies with the frequency of applied voltage, temperature of the material, moisture present, and thickness of dielectric. Somewhat irregular ratings are often the case at higher frequencies because of the difficulty about placing a solid dielectric in perfect contact with the plates—even under great pressure. Where high rf potentials are involved and where a small lumped capacitance is required, the vacuum unit is more satisfactory than most other types because of its smaller size and more stable breakdown rating.

Pressurized, gas-filled capacitors made by E. F. Johnson Co. follow a basic design. Fixed and variable units both have copper-plated, drawn-steel shells in 6-in. diam. Miter-gear drive serves on variable version shown here



Disposition of internal elements is here illustrated for an early Johnson pressure capacitor. This type is described as partially variable. Diameter is 10 in. and the shell is thick-walled, seamless, and heavily copper plated

Power Loss Factors

Dielectric of most capacitors has a dual or multiple nature, and no solid or liquid material is completely free from power loss. For example, in a typical mica capacitor, there is mica between the plates, and there is also some insulator such as a plastic or ceramic material in contact with the leads. The general effect of this outer insulator can usually be disregarded, except at ultrahigh frequencies or in devices of very small capacitance. In vacuum units, the glass envelope acts as an outer dielectric, but the area of contact with the end-cups is so small, and the dielectric path so long, that the effects of the glass are negligible. For all practical purposes, the high vacuum can be considered the sole dielectric, and the capacitor has an exceptionally high Q.

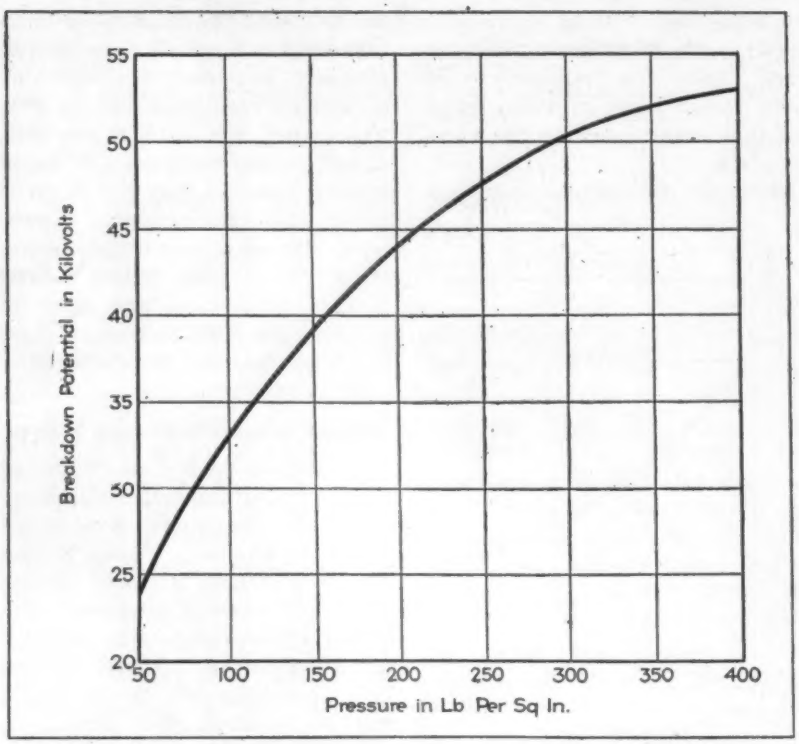


FIG. 3. Rise in breakdown potential with pressure increase in this curve results from greater opportunities for collision between a travelling electron and nitrogen molecules as more of them occupy a given space. This inhibits ionization

Power losses of solid and liquid insulators include those due to insulation resistance, dielectric absorption, and hysteresis. These losses are a function of frequency, rising sharply at very short wavelengths. Loss factor is probably the best criterion of the efficiency of a capacitor, and can be found by multiplying the dielectric constant by the power factor. Phase displacement due to the glass and high vacuum dielectrics of a vacuum capacitor is obviously very slight, resulting in a low loss angle and a correspondingly-low loss factor. Resistance of the plates and leads, skin effect, and eddy currents are other minor sources of power loss, but dielectric absorption and hysteresis losses in this kind of capacitor are approximately nil.

There is, then, an extremely high ratio of susceptance to conductance, because of low dielectric loss. The only other possibility of power loss would be a conduction current of an ionic character through the

Two sizes of Lapp Insulator Co. pressurized capacitors show aluminum shells, gear head drives, and indicator pressure gages. Also featured are adjustable provisions for external flashover

traces of gas between the plates. This occurs, however, only at dc or low-frequency audio voltages above 7,500 v. At higher audio frequencies, this power loss disappears. Total resistance losses in a vacuum capacitor have been found to be negligible up to 50 Mc or more. The unusually high Q of this type makes it useful for tank circuits of radiotelephone transmitters, where Q of the resonant circuit must be large enough to avoid splatter of the signal due to amplification of stray harmonics.

Frequency Affects Capacitance

At frequencies below about 50 Mc, the capacitance of any unit (neglecting edge effects) depends solely upon the type of dielectric, the effective surface area of the plates, and the spacing between them. However, the permittivity of practically all insulators varies somewhat when a voltage of very high frequency is applied. This variation may be the result of a change in volume of the insulator due to electrostriction or electrostatic heating, evaporation of adsorbed moisture, or possibly other factors.[4] The only exceptions are a few types of solid materials, such as polymerized styrene, whose dielectric constant is virtually independent of frequency over a wide range.

Fluctuation of permittivity is not the only cause of frequency variation of capacitance, however. For example, typical variable air capacitors are relatively stable, but their capacitance is likely to be affected somewhat by atmospheric moisture, temperature change, age and vibration. The dielectric constant of dry air at normal pressure is about 1.000558,[5] and that of water, about 85. Thus, a slight increase of humidity will raise the capacitance of such a unit. The dielectric constant of the vacuum capacitor is probably very close to 1, and is materially unaffected by external factors.

Mechanical Structure

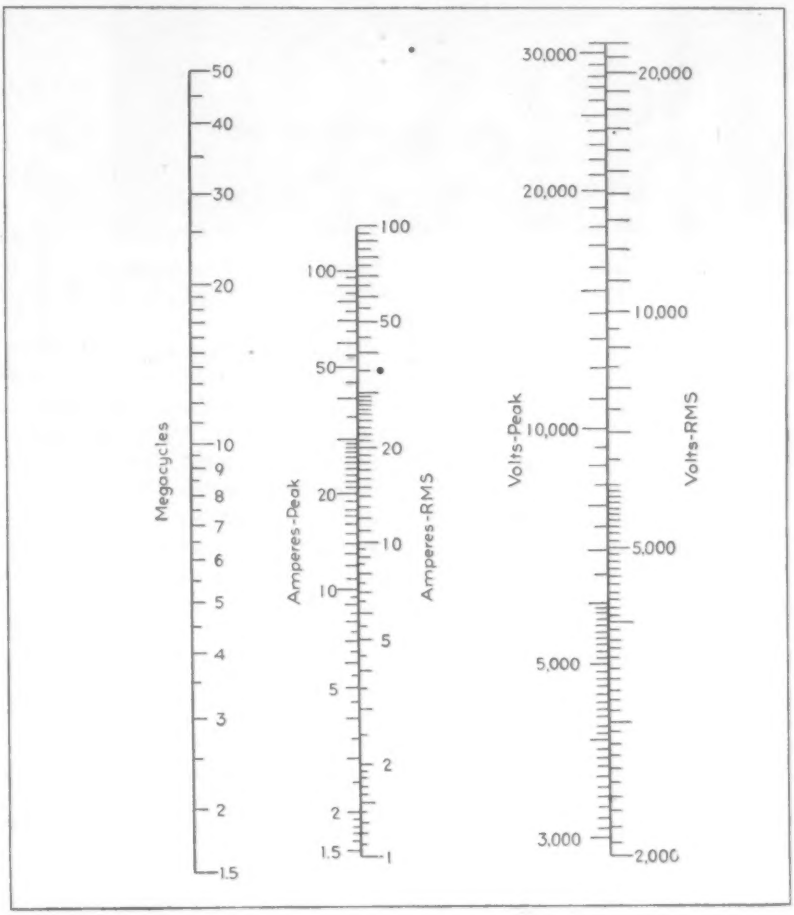
Certain types of vacuum capacitors are designed so that thermal expansion of the boro-silicate glass is the same as that of the metal end-cups which are iron-nickel-cobalt alloy. This careful matching of temperature coefficients prevents change of capacitance with temperature. Rugged, cylindrical-plate construction also leads to more stable values than those of clamped, parallel-plate, air units. These are usually subject to stresses in the insulating supports due to vibration, aging, or bending of plates.

Geometric capacitance is not identical with effective capacitance —the value actually used in practice. For example, equivalent series capacitance of an air, vacuum, or pressure unit is given by the equation

$$C_e = \frac{C}{1 - LC\omega^2} \qquad (1)$$

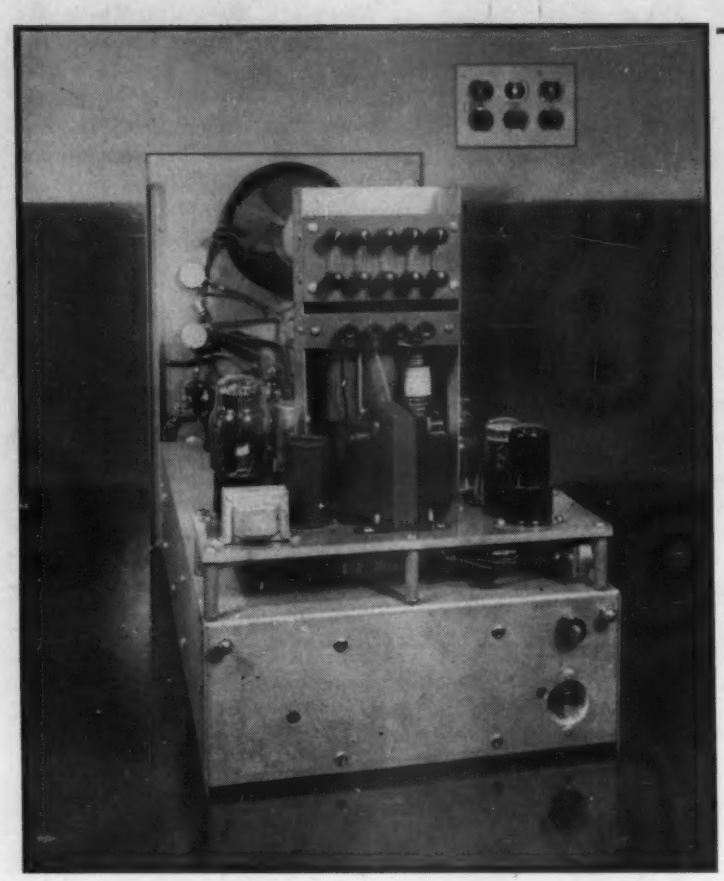
where C is total geometric capacitance, L is inductance of the plates and leads, and $\omega = 2\pi f$. From this it can be seen that plates and leads of the capacitor cause a rise in effective capacitance with increasing frequency. A good quality variable

(*Continued on page* 320)



Relationships between current, voltage, and frequency for 50$\mu\mu$f vacuum capacitors of the types in an accompanying illustration are established for reference on this nomograph. Straight line passing through any two factors reveals the third

Beam Blanking C



Rear view of a commercial cathode-ray oscilloscope in which the beam-blanking circuit has been incorporated

A three-tube electronic unit permits photographing a complete transient trace on a cathode-ray oscilloscope screen with high detail and no fogging. Arrival of transient trips a trigger circuit, releasing the blanked beam, and provides a dotted "Z" timing wave

By WALTHER RICHTER

Allis-Chalmers Manufacturing Co., Milwaukee, Wisc.

MOST modern cathode-ray tubes are provided with a grid by means of which it is possible to interrupt the electron beam producing the spot on the screen. Commercial oscilloscopes containing these tubes are provided with a control which applies a negative voltage to this control grid and makes it possible to interrupt the beam at will.

For the photography of transients, some of the instruments provide a so-called "single-sweep" feature. When the single-sweep circuit is put into operation, the beam is biased sufficiently so that the spot does not appear on the screen, but the starting of the transient or any desired tripping impulse is used to sweep the spot across the screen just once. This is a highly desirable addition, but there are two points which prove to be somewhat undesirable.

First, even with the beam biased so as not to strike the screen, there are scattered electrons striking the screen, leading to a reasonably strong background illumination. If for any reason the camera shutter has to be opened an appreciable time before the expected transient begins, an undesirable amount of fogging of the film takes place.

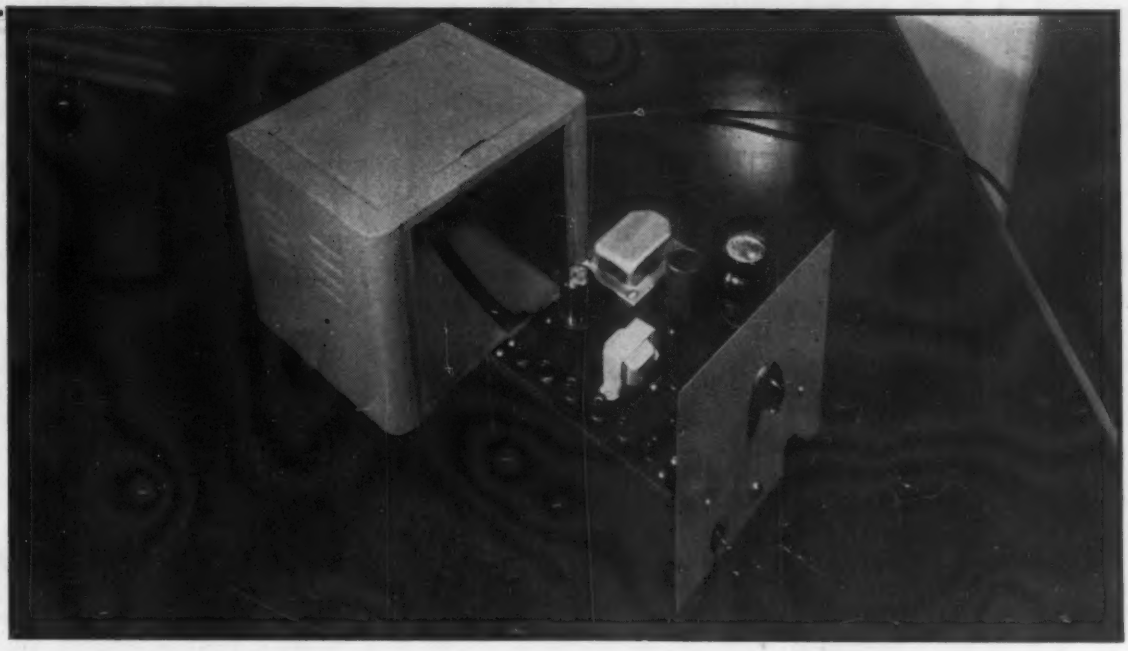
Secondly, if it is desired to obtain a picture of the complete transient, then it is of course necessary to adjust the rate of the single sweep to such a value that the time taken by one sweep is equal to the total time of the transient. The resulting oscillogram can therefore not be any longer than a single sweep. It is quite obvious that considerable detail of the transient may become lost in the picture due to the need of compressing it into a single sweep.

Suppose now that instead of only one, we permit five sweeps, with the rate of sweep adjusted to such a value that one sweep will take place in a time equal to one-fifth of the time of the transient, or in other words, the time of five sweeps will equal the duration of the transient. The oscillogram will then consist of five branches, each one representing one-fifth of the transient.

An example of a transient as it would appear with a single sweep appears in Fig. 1(a), while Fig. 1(b) shows this same transient spread over five sweeps. Corresponding segments in the two traces are similarly marked.

With the number of sweeps limited to a reasonable value, such as 5, there is usually no difficulty in piecing the individual branches properly to each other since the displacement from the zero line and the slope must be the same at the right and left hand edges of the oscillogram. The piecing together of the segments may be further facilitated by having enough brilliancy so that the return sweep produces a faint trace which then connects the proper branches with each other. It is

Circuit for Oscilloscopes



Complete beam-blanking equipment built as a separate unit for use with any oscilloscope

evident that such a picture will reveal finer detail of the transient.

Film-Fogging Problem

It is entirely feasible to obtain this result by designing an electronic circuit that will make the sweep repeat itself for a definite number of cycles, but this still does not remove the possibility of fogging. Therefore a more desirable solution would be one in which the sweep operates continuously, and the beam is released only for the desired exposure. In principle, this is a rather simple procedure; all one has to do is to keep the grid of the cathode-ray tube sufficiently negative to cause cut-off of the beam, and reduce this negative bias to the proper value for the time of exposure.

From a practical point of view, however, there is a serious handicap standing in the way of an easy solution, due to the following condition: when operating a cathode-ray tube, the average potential of the deflection plates should be near the anode potential. This condition is ordinarily met by placing the anode of the cathode-ray tube at or near ground potential, which in turn places the cathode at a negative potential amounting to a thousand volts or more with respect to ground. Since the grid must be made negative with respect to the cathode, this means that the operating potential of the grid is also one to several thousand volts negative with respect to ground.

Insulating Problems

With this in mind, it is clear that the problem of shifting the grid potential with respect to the cathode by 100 volts or so is not too easy. One could install a relay, the coil of which would be insulated sufficiently from the contact structure and by means of which the grid voltage could be shifted from one value to another, but any mechanical device of this nature with its mechanical and electrical inertia and the possibility of bouncing contacts is practically ruled out.

The circuit described in the following paragraphs is nothing but a trigger circuit which can be tripped by an impulse transmitted through a capacitor to the proper point in the circuit. The whole trigger circuit and its power supply is insulated from ground for a voltage equal to the operating voltage of the cathode-ray tube. The components are mounted on an insulating panel or on a steel chassis which in turn is insulated from its housing or from the chassis of the oscilloscope.

The only special component needed is a power transformer for the trigger circuit, the primary winding of which is insulated from the core and the other windings for a voltage equal to the operating voltage of the cathode-ray tube. If such a transformer is not available, a 1:1 insulating transformer may be employed which permits the use of any standard small power transformer for the trigger circuit.

Provisions are also made to apply a dotting or "Z" signal to the grid of the cathode-ray tube. The circuit is so arranged that dotting and tripping do not interfere with each other.

Operation of Trigger Circuit

Figure 2 shows the diagram of the complete circuit. The tripping circuit consists of a double triode, VT_1, which with its associated resistors R_1, R_2, R_3, and R_1', R_2' and R_3' forms a trigger circuit. When one

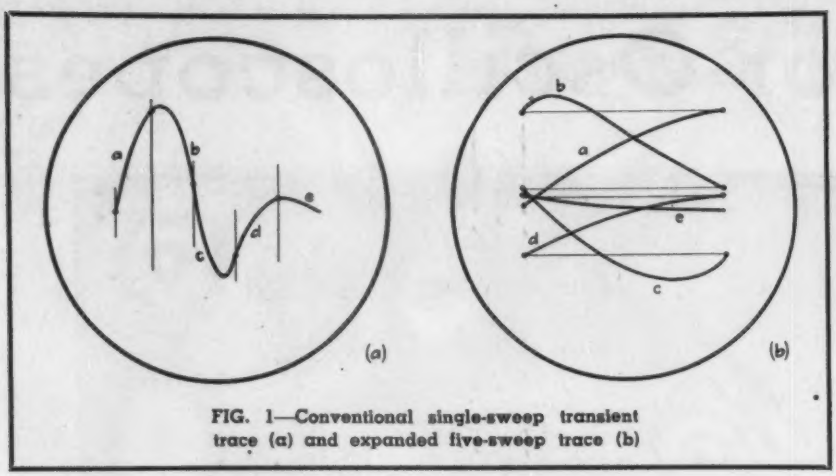


FIG. 1—Conventional single-sweep transient trace (a) and expanded five-sweep trace (b)

section of the tube is conducting, the other section is automatically biased to cut-off. Consequently, either one or the other section is conducting, but never both at the same time. An impulse transmitted to the grid of one section, in such a direction as to change the state in which it is at that instant, will therefore cause the circuit to go from one condition to the other.

One of the sections of VT_1, designated as *a*, performs the desired control action on the grid of the cathode-ray tube. This is accomplished in the following manner: when left-hand section *a* is nonconducting, the drop across the plate resistor R_1 is small, since the only current flow through it is due to the current flowing through the high resistances R_2 and R_3. Point *A* will therefore be only a few volts negative with respect to the positive end of the power supply. The cathode of one section of the double diode VT_2 is connected to point *A*. The anode of this section is connected through resistor R_4 to point D on potential divider R_5, which is adjusted so that *D* is negative with respect to point *A* as long as tube section *a* is non-conducting. Consequently, no current flows through R_4, and the potential of the grid of the cathode-ray tube with respect to the cathode is simply determined by the position of the arm on R_5. This permits manual adjustment of the grid voltage of the cathode-ray tube to give any desired brilliancy, or to blank the beam if so desired.

If section *a* of VT_1 is made conducting, however, the plate current will cause a large voltage drop across the plate resistor R_1. This makes point *A* negative with respect to point *D*, and consequently there will be a flow of current established through the right-hand section of double diode VT_2. Current flow is in the direction from point *D* through the diode to point *A* and is therefore such as to increase the grid bias of the cathode-ray tube over and above any value to which it may have been adjusted by the slider of R_5. Consequently, by triggering the double triode from one condition to the other, a release or blanking of the beam may be obtained. The tripping impulse may be administered to the grid of either section. A negative impulse administered to the grid of section *a*, or a positive impulse administered to the grid of section *b* will make section *a* nonconducting and thus release the beam. Impulses of the opposite polarity will correspondingly blank the beam again.

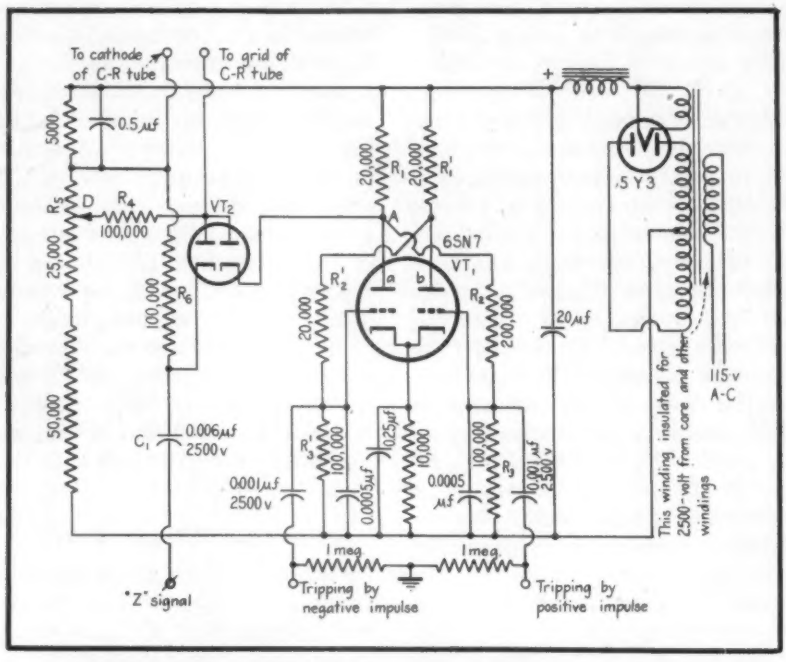


FIG. 2—Complete beam-blanking circuit, with power supply and provisions for applying a dotted "Z" timing voltage to the cathode-ray tube

Production of Dotting Signal

The left-hand section of the double diode is used to provide the "Z" or dotting signal. It is seen that the application of the proper type of signal (preferably of a square-wave shape in order to avoid defocussing during the duration of the dot) through blocking capacitor C_1 causes an alternating current to flow through resistor R_6 which (during its negative half-wave) will cause a current flow through the left-hand section of the double diode, thus periodically biasing the grid of the cathode-ray tube.

It should be noted that blanking and releasing require only an impulse and not the maintaining of a certain voltage during the time that the beam is to be released.

The complete equipment can be made as a separate device which can be used with any oscilloscope on which the cathode and grid terminals have been brought out, or can be permanently incorporated in one of the oscilloscopes available on the market.

REMOTE MONITOR for Directional Broadcasting

Direct measurement of the null point in the radiation pattern from a directional antenna system is accomplished with a modified receiver which gives a continuous microammeter reading at the transmitter

By M. A. O'BRADOVICK *Transmitter Supervisor Station KMPC North Hollywood, Calif.*

GREATER USE of directional antenna systems by broadcast stations has increased the importance of means for measuring and keeping a check on the radiation patterns.

Instruments for indicating phasing in the several elements of directional arrays have been specially devised for the purpose and built in as permanent parts of some transmitters. This measures the means by which the desired result is produced, but is not a direct check on the radiation pattern itself, or what is of most importance, the strength of the signal radiated in the minimum signal or null-point direction.

A means of checking signal intensity directly provides an indication of the signal radiated toward the channel-sharing station with which interference must be avoided.

Unit in Continuous Service

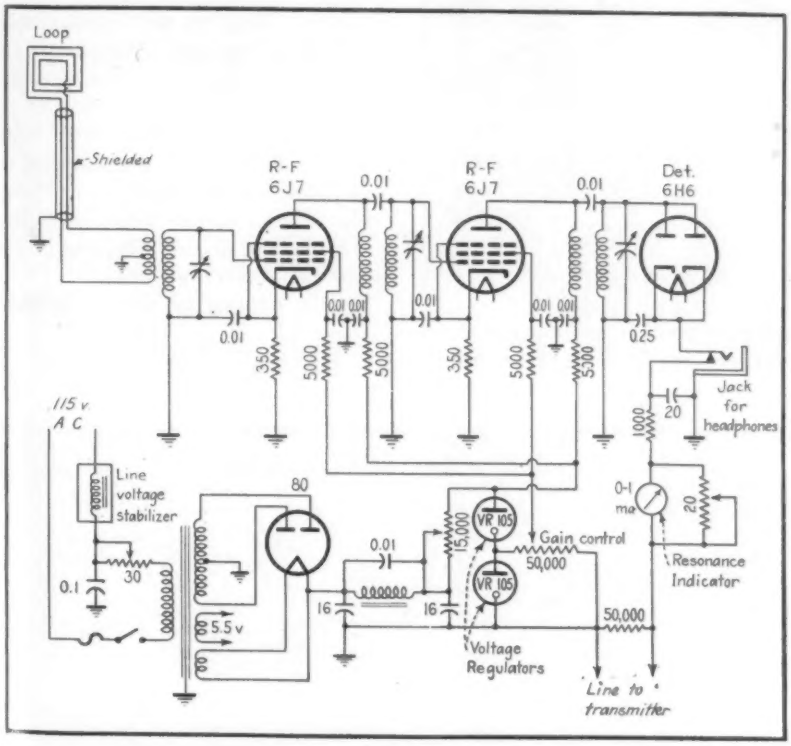
Among the first examples of a signal-monitoring system of this type is one installed for the 10 kw transmitter of KMPC, North Hollywood, Calif, the last of this power to be installed before the war. Operating on 710 kc, KMPC shares the channel with KIRO, Seattle, Wash., 960 miles away.

Mounted on a pole, the remote monitoring unit receives a signal from the antenna array to the right of the pole in the background and 1½ miles away. Receiver diode current goes back to the transmitter by phone line

At a distance of 1½ miles from the three 300 ft towers which make up the directional array, a simple type of monitoring receiver is installed on a 25 ft pole, surmounted by a loop antenna. The receiver operates continuously, energized from a 115-v line on the pole. The dc developed in the diode detector of the receiver is sent over a telephone line back to the transmitter, where it actuates a microammeter on the operator's console.

Steady deflection of this meter affords a constant and directly

(*Continued on page 270*)



Circuit of the remote monitor. The 30-ohm rheostat in the power-transformer primary circuit reduces the line voltage to extend service life

SINGLE-INDUCTO

Advantages over tuned interstage transformers in wide-band r-f and video amplifiers are discussed, performance is analyzed, expressions are set up for total voltage gain, bandwidth and skirt steepness ratio, and design curves are given for band widths up to 5 Mc

By C. T. McCOMB and A. P. GREEN

Naval Research Laboratory
Washington, D. C.

OF THE MANY METHODS of coupling between stages of tuned amplifiers, probably the simplest is the common single-inductor coupling network. While the single inductor does not possess the versatility of the tuned transformer or of other more elaborate coupling networks, neither does it entail the complexity of design, manufacture, and alignment of other types of coupling.

Consideration of the characteristics of the single-inductor coupling network is made under conditions where the center frequency and bandwidth requirements are such that the single inductor exhibits its most useful features. The scope of application for this treatment of the single inductor is limited by only a few basic restrictions. In Fig. 1 is shown a schematic circuit for use of the single inductor in a coupling network. Variations of this circuit are of course possible, but they will not change the basic behavior of the network.

Figure 2 gives the fundamental equivalent network involving the inductor. The output capacitance of the preceding tube, the input capacitance of the following tube, and the distributed capacitance of the inductor and circuit are considered as a single shunt capacitor with respect to the inductor in the equivalent circuit.

In the analysis of the network, it

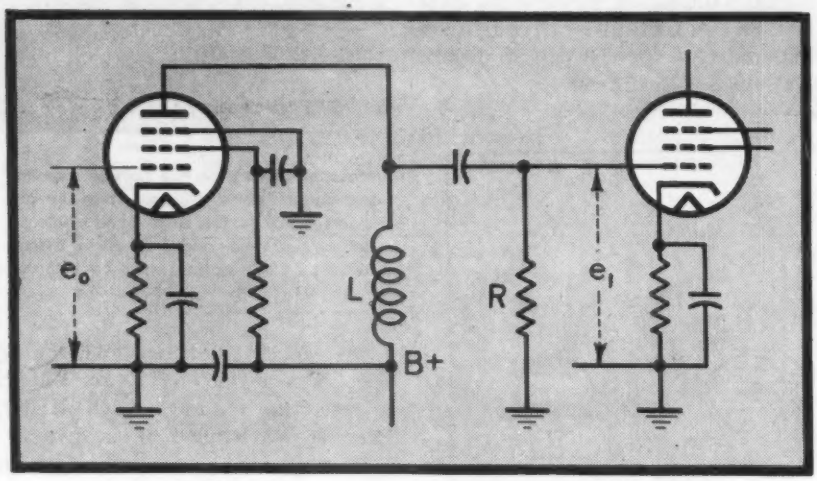


FIG. 1—Circuit using single inductor *L* in coupling network

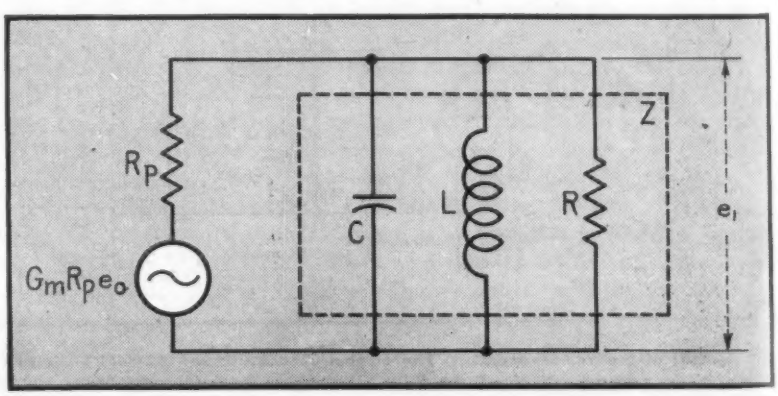


FIG. 2—Equivalent circuit of amplifier stage using a single-inductor coupling network

COUPLING NETWORKS

is assumed as a first restriction that the inductor has a sufficiently high Q so that its effective inherent shunt resistance is large compared to the size of the damping resistor used in the coupling network. As a second restriction, the plate resistance of the preceding tube is also considered to be very large compared to the damping resistor. The first restriction is merely for the purpose of analysis so that the damping action in the network can be considered as being due solely to a lumped shunt resistor. The second restriction limits the use of this analysis to those applications where the bandwidth requirements are such that the necessary damping resistor will be small compared to the effective plate resistance of the tube. This last condition does not place a severe limitation on the usefulness of this work, because the great majority of all video modulation applications will fall within this range.

Total Voltage Gain for N Stages

An examination of the equivalent network of Fig. 2 shows that the voltage gain for a single stage is given by the expression

$$V.G. = \frac{e_1}{e_0} = \frac{g_m R_P Z}{R_P + Z} \qquad (1.10)$$

With the above-discussed second restriction that R is small compared to R_P, and since Z can never be greater than R, then for this treatment Z will be small compared to R_P and we will have for one stage of amplification

$$V.G. = e_1/e_0 = g_m Z \qquad (1.11)$$

For N identical stages, as in Fig. 3, the total gain at any frequency, Γ_f, will be

$$\Gamma_f = (g_m Z)^N \qquad (1.20)$$

From the equivalent circuit, Z can be expressed by

$$Z = \frac{1}{\frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right)} \qquad (1.30)$$

It is apparent that Z is a maximum and equals R when $\omega C = 1/\omega L$. If we let $\omega = \omega_o$ when $Z = R$ (at resonance), then $\omega_o C = 1/\omega_o L$ or $L = 1/\omega_o^2 C$, we have

$$Z = \frac{1}{\frac{1}{R} + j\left(\omega C - \frac{\omega_0^2 C}{\omega}\right)} \qquad (1.31)$$

and the total gain will be

$$\Gamma_f = (g_m Z)^N = g_m{}^N \left[\frac{1}{\frac{1}{R} + j\left(\omega C - \frac{\omega_0^2 C}{\omega}\right)}\right]^N \qquad (1.21)$$

At resonance,

$$\Gamma_{f_o} = (g_m R)^N \qquad (1.22)$$

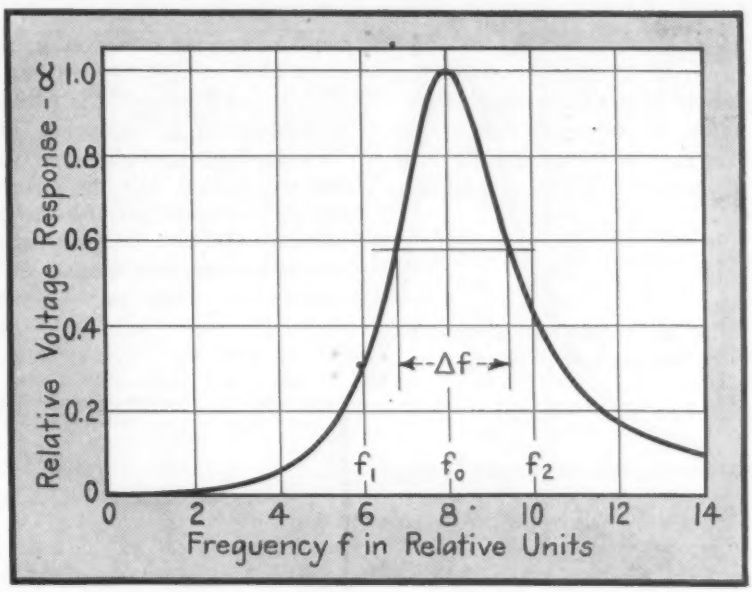


FIG. 4—Voltage response characteristic of an amplifier stage using a single-inductor coupling network, showing significance of band width for any specific value of relative voltage response off the resonant frequency

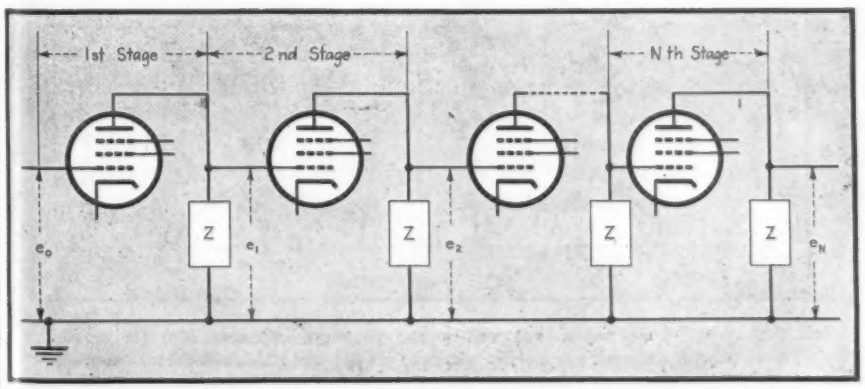


FIG. 3—Use of single-inductor coupling networks (represented by equivalent impedance Z) in N identical stages

We can now advantageously express the total voltage gain at any frequency as a fraction, α, of the total voltage gain at resonance, thus:

$$\Gamma_f = \alpha\Gamma_{f_0} = \alpha(g_m R)^N \qquad (1.23)$$

With this expression for the total voltage gain at any frequency expressed as a function of some of the known constants of the network and the determinable factor, α, we have a useful means for predicting the behavior of any single-inductor type tuned amplifier.

General Bandwidth for N Stages

Since the total gain and the bandwidth are the two basic requirements for any tuned amplifier, it is necessary that an expression be obtained relating these quantities to the known constants of the network.

From Eq. (1.21) and (1.23) for total voltage gain,

$$\Gamma_f = \alpha\,(g_m R)^N$$

$$= g_m{}^N\left[\frac{1}{\frac{1}{R}+j\left(\omega C-\frac{\omega_0{}^2C}{\omega}\right)}\right]^N \qquad (2.10)$$

We are interested only in the magnitude of the impedance at any frequency so we may reduce the complex expression on the right to a real number and cancel out $g_m{}^N$, thus

$$\alpha R^N = \left[\frac{1}{\frac{1}{R^2}+\left(\omega C-\frac{\omega_0{}^2C}{\omega}\right)^2}\right]^{N/2} \qquad (2.20)$$

Taking the $N/2$th root of the expression, we have

$$\alpha^{2/N}R^2 = \frac{1}{\frac{1}{R^2}+\left(\omega C-\frac{\omega_0{}^2C}{\omega}\right)^2} \qquad (2.21)$$

Rearranging terms results in the relation

$$(\omega^2-\omega_0{}^2)^2 = \frac{\omega^2(1-\alpha^{2/N})}{\alpha^{2/N}R^2C^2} \qquad (2.22)$$

and since $\omega = 2\pi f$ we can write

$$(f^2-f_0{}^2)^2 = \frac{f^2(1-\alpha^{2/N})}{4\pi^2\alpha^{2/N}R^2C^2} \qquad (2.23)$$

then

$$f^2-f_0{}^2 = \pm\frac{f\sqrt{1-\alpha^{2/N}}}{2\pi\alpha^{1/N}RC} \qquad (2.24)$$

From Fig. 4 it is seen that for any relative voltage response, α, there are two values of f. These frequencies will be designated f_1 and f_2; since they must be positive real numbers, we have for the solutions of Eq. (2.24)

$$f_2{}^2-f_0{}^2 = \frac{f_2\sqrt{1-\alpha^{2/N}}}{2\pi\alpha^{1/N}RC} \qquad (2.25)$$

and

$$f_1{}^2-f_0{}^2 = \frac{-f_1\sqrt{1-\alpha^{2/N}}}{2\pi\alpha^{1/N}RC} \qquad (2.26)$$

Eliminating f_0 from the above equations and using the notation for general bandwidth, $\Delta f = f_2 - f_1$, we have

$$f_2{}^2-f_1{}^2 = (f_2+f_1)\frac{\sqrt{1-\alpha^{2/N}}}{2\pi\alpha^{1/N}RC} \qquad (2.27)$$

Then, since $f_2{}^2 - f_1{}^2 = (f_2 + f_1)(f_2 - f_1)$,

$$\Delta f = \frac{\sqrt{1-\alpha^{2/N}}}{2\pi\,\alpha^{1/N}RC} \qquad (2.30)$$

For convenience of analysis, this expression for general bandwidth can be given most simply as[6]

$$\Delta f = \frac{\sqrt{\frac{1}{\alpha^{2/N}}-1}}{2\pi RC} \qquad (2.31)$$

This relationship shows the functional variation of the bandwidth of the amplifier with respect to the circuit constants and the relative voltage response ratio at which the bandwidth is considered. It shows that if R and C are fixed, both the bandwidth at any given relative response, α, and the total voltage gain (since $\Gamma_f = \alpha(g_m R)^N$) will remain constant regardless of the value of the inductance, L, employed. Thus it is seen that any inductance variation will change only the resonant frequency and will have no effect on the bandwidth or total gain.

An important relationship exists between the high and low frequencies, f_2 and f_1, for any relative response, α, and the resonant frequency, f_0, of the coupling network. Dividing Eq. (2.25) by (2.26), we obtain

$$\frac{f_2{}^2-f_0{}^2}{f_1{}^2-f_0{}^2} = -\frac{f_2}{f_1} \qquad (3.10)$$

Solving this for $f_0{}^2$ gives

$$f_0{}^2 = f_1 f_2 \qquad (3.11)$$

This establishes the well-known formulation that the resonant frequency is the geometric mean of the high and low response frequencies at any relative response of the amplifier. It follows that the response of an amplifier is thus geometric with respect to its resonant frequency, and a linear frequency plot of the amplifier characteristic will appear asymmetrical. For this reason a logarithmic frequency scale is usually employed so that the characteristic will appear symmetrical.

Skirt Steepness Ratio

An interesting characteristic of the behavior of N stages of a single-inductor coupling network can be drawn from a consideration of the expression in Eq. (2.31) for Δf. The quality of an amplifier is partially determined by its response to near signals relative to its desired bandwidth response. This characteristic is important in the signal-to-noise ratio of the amplifier since the total area under the response curve contributes to noise energy,

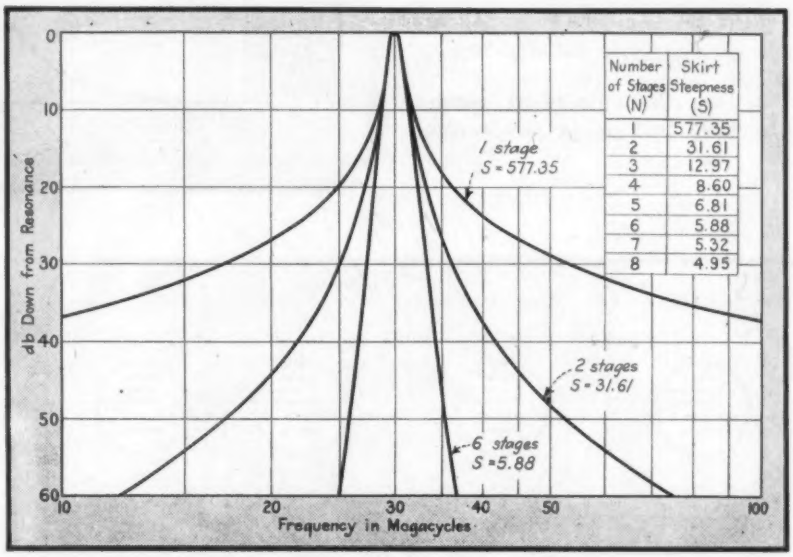


FIG. 5—Skirt steepness ratio values and response characteristics for amplifiers having different numbers of identical stages using single-inductor coupling

while only an area proportional to the signal bandwidth contributes to the signal energy. This degree of quality is expressed as a factor, skirt steepness S, which is defined as the ratio of the bandwidth at −60 db response to the bandwidth at −6 db response. This ratio is seen to be an inverse index of the quality of rejection of the amplifier in that as the ratio becomes smaller, the response to near signals will be less. From Eq. 2.31 for Δf and since for −60 db response $\alpha = 0.001$ and for −6 db response $\alpha = 0.5$, we have

$$S = \frac{{}^{\prime}\Delta f_{-60db}}{{}^{\prime}\Delta f_{-6db}} = \frac{\sqrt{\frac{1}{(0.001)^{2/N}} - 1}}{\sqrt{\frac{1}{(0.5)^{2/N}} - 1}} \qquad (4.10)$$

It is seen from this expression that the skirt steepness is dependent only upon the number of stages and not upon any of the other characteristics of the amplifier. The ratio, S, for amplifiers of from one through eight stages is given in Fig. 5, along with representative response characteristics of amplifiers with different numbers of stages. A logarithmic frequency scale is used as discussed above in order to obtain symmetrical curves. The three response characteristics presented are all down 6 db at a bandwidth of 2 Mc with a center frequency of 30 Mc. The difference between the characteristics is due to the number of stages used in each.

It is seen that a very great improvement in skirt steepness is obtained in going from one stage to any greater number of stages. The much more desirable characteristic shape of the response of six stages compared to that of two stages is also evident from the curves. This decided increase in the rejection of near signals is so pronounced that in many applications the use of additional stages will be justified even though the required total gain could be obtained with a fewer number of stages.

Effective Bandwidth for N Stages

The effective bandwidth of a resonant response characteristic is defined as the bandwidth of an assumed rectangular response of height equal to the response of the particular network at resonance and of area equal to its total integrated power response. In order to apply this definition it is necessary to treat the power gain of N stages. This is proportional to the square of the total voltage gain. From Eq. (1.22) for Γ_{f_o} we can write for the power gain at resonance:

$$\text{Total power gain at } f_o = P_{f_o} = K\Gamma_{f_o}^2 = K(g_m R)^{2N} \qquad (5.10)$$

where K is the impedance proportionality constant for the particular general circuit under consideration. From this we have, in a manner similar to Eq. (1.23),

$$\text{Total power gain at } f = P_f = \beta P_{f_o} = K\beta(g_m R)^{2N} \qquad (5.11)$$

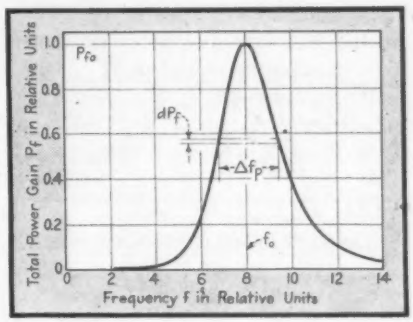


FIG. 6—Example of power response characteristic, the area of which is utilized in determining the effective bandwidth of a stage using a single-inductor coupling network

where β is the fractional power response factor of the total power gain at resonance. It is seen that β is the factor corresponding to α in Eq. (1.23) for voltage response.

Since we are interested in obtaining a relationship in terms of the maximum power response and the bandwidth, we can write

$$K\beta(g_m R)^{2N} = Kg_m^{2N}\left[\frac{1}{\frac{1}{R} + j\left(\omega C - \frac{\omega_0^2 C}{\omega}\right)}\right]^{2N} \qquad (5.20)$$

This becomes

$$\beta R^{2N} = \left[\frac{1}{\frac{1}{R} + j\left(\omega C - \frac{\omega_0^2 C}{\omega}\right)}\right]^{2N} \qquad (5.21)$$

Reducing the right side of the expression to a real number, since we are interested only in the absolute magnitude, and taking the square root of both sides of the equation gives

$$\beta^{1/2} R^N = \left[\frac{1}{\frac{1}{R^2} + \left(\omega C - \frac{\omega_0^2 C}{\omega}\right)^2}\right]^{N/2} \qquad (5.22)$$

Comparison of this form of the equation with the similar form obtained in the consideration of general bandwidth in Eq. (2.20), gives us immediately the form of the solution. We see that α in Eq. (2.20) will be replaced by $\beta^{\frac{1}{2}}$. Using the notation Δf_P to indicate the bandwidth with respect to the power response curve, we have

$$\Delta f_P = \frac{\sqrt{\frac{1}{\beta^{1/N}} - 1}}{2\pi RC} \qquad (5.30)$$

This equation now gives the necessary expression for completing the evaluation of the defined effective bandwidth. We may now write the defining integral for the total area under the power response curve. We shall take the equation for Δf_P, which is the expressed bandwidth at any relative response P_f, and integrate with respect to dP_f over the range of zero to P_{f_o} which is the maximum power response. This will give the total area under the curve, an example of which is given in Fig. 6.

$$\text{Area under power curve} = \int_0^{P_{f_o}} \Delta f_P \, dP_f \qquad (5.40)$$

Applying the definition for effective bandwidth and noting it as Δ_{f_e}, we can write

$$\Delta f_e = \frac{\int_0^{P_{f_o}} \Delta f_P \, dP_f}{P_{f_o}} \qquad (5.50)$$

Using Eq. (5.10), (5.11), and (5.30), we can substitute in Eq. (5.50) as follows:

$$\Delta f_e = \frac{\int_0^{P_{f_o}} \frac{\sqrt{\frac{1}{\beta^{1/N}} - 1}}{2\pi RC} \, d[K\beta(g_m R)^{2N}]}{K(g_m R)^{2N}} \qquad (5.51)$$

Noting in Eq. (5.51) that the variable of relative response is β, we can perform the indicated differentiation, simplify the expression, and evaluate the new limits of integration for β. This gives

$$\Delta f_e = \frac{1}{2\pi RC}\int_0^1 \sqrt{\frac{1}{\beta^{1/N}} - 1} \; d\beta \qquad (5.52)$$

which is the definite integral expression for the effective bandwidth.

The above equation does not lend itself readily to integration, so we shall use a convenient substitution to reduce the expression to an easily integrated form. Letting $\beta = \cos^{2N}\phi$,

$$d\beta = -2N\cos^{2N-1}\phi \sin\phi \, d\phi$$

and the equation becomes

where

$$\Gamma_x = (g_{mx}R_x)^N \qquad (6.21)$$

Thus the family of curves given in Fig. 7 is perfectly general with the above equation.

With the desired total gain fixed in an amplifier and with the value of g_{mx} established to obtain that gain with the determined number of stages, the necessary value of shunt resistance R_x is obtained from Eq. (6.21) for Γ_x thus

$$R_x = \frac{\Gamma_x^{1/N}}{g_{mx}} \qquad (6.30)$$

Example of Use of Design Curves

In order to demonstrate the extreme simplicity of application of the design curves given in Fig. 7 an example will be presented.

Assume that an amplifier is desired to have a total voltage gain of 10,000 and an effective bandwidth of 2.0 Mc. The resonant frequency is not involved in the determination of either the number of stages or the shunt resistor R, as was discussed above. First, observation of Fig. 7 shows that for the conditions required the amplifier will have either 4 or 5 stages, with variations in C and g_m fixing the final choice. Four stages gives insufficient gain for the operational conditions of $C = 25$ $\mu\mu$f and $g_m = 5000$ μmhos that were chosen for Fig. 7, while five stages gives too much gain for these conditions. Now assuming that the circuit layout is such that we will have 22 $\mu\mu$f capacitance instead of 25 $\mu\mu$f used in Fig. 7, we see from the equation for Γ_x that this will raise the total gain.

Let us take the two cases of 4 and 5 stages and compute what the operating g_{mx} and the required shunt resistor R_x will be for our problem. For 4 stages, from Fig. 7 we have

$$\Gamma_x = 10{,}000 = 3720\left(\frac{g_{mx}}{5000}\Big/\frac{22}{25}\right)^4$$

Solving, we have

$$g_{mx} = 5000 \times \frac{22}{25}\left(\frac{10{,}000}{3720}\right)^{1/4} = 5640\ \mu\text{mhos}$$

Therefore,

$$R_x = \frac{(10{,}000)^{1/4}}{5640 \times 10^{-6}} = \frac{10}{0.00564} = 1773\ \text{ohms.}$$

We see that to get exactly the conditions set down for the amplifier of the problem when four stages are used, the operating g_m of the tubes would be raised slightly above the value used in Fig. 7. Finding this value, we can compute the value of R_x.

Now taking our amplifier to have five stages, we obtain from Fig. 7

$$\Gamma_x = 10{,}000 = 15{,}100\left(\frac{g_{mx}}{5000}\Big/\frac{22}{25}\right)^5$$

Solving, we have

$$g_{mx} = 5000 \times \frac{22}{25}\left(\frac{10{,}000}{15{,}100}\right)^{1/5} = 4055\ \mu\text{mhos}$$

therefore,

$$R_x = \frac{(10{,}000)^{1/5}}{4055 \times 10^{-6}} = \frac{6.3095}{0.004055} = 1554\ \text{ohms.}$$

For five stages we see that the operating g_m of the tubes is reduced below that assumed for Fig. 7. R_x is then computed as in the previous case using the new g_{mx}.

From the above solution to the problem we see that the curves of Fig. 7 are completely definitive of the behavior of the general single-inductor coupling network and that for any particular amplifier the consideration of only the capacitance C that will be involved in the circuit need be determined. Then the operating g_m for the tubes and the required value of R_x can be determined directly.

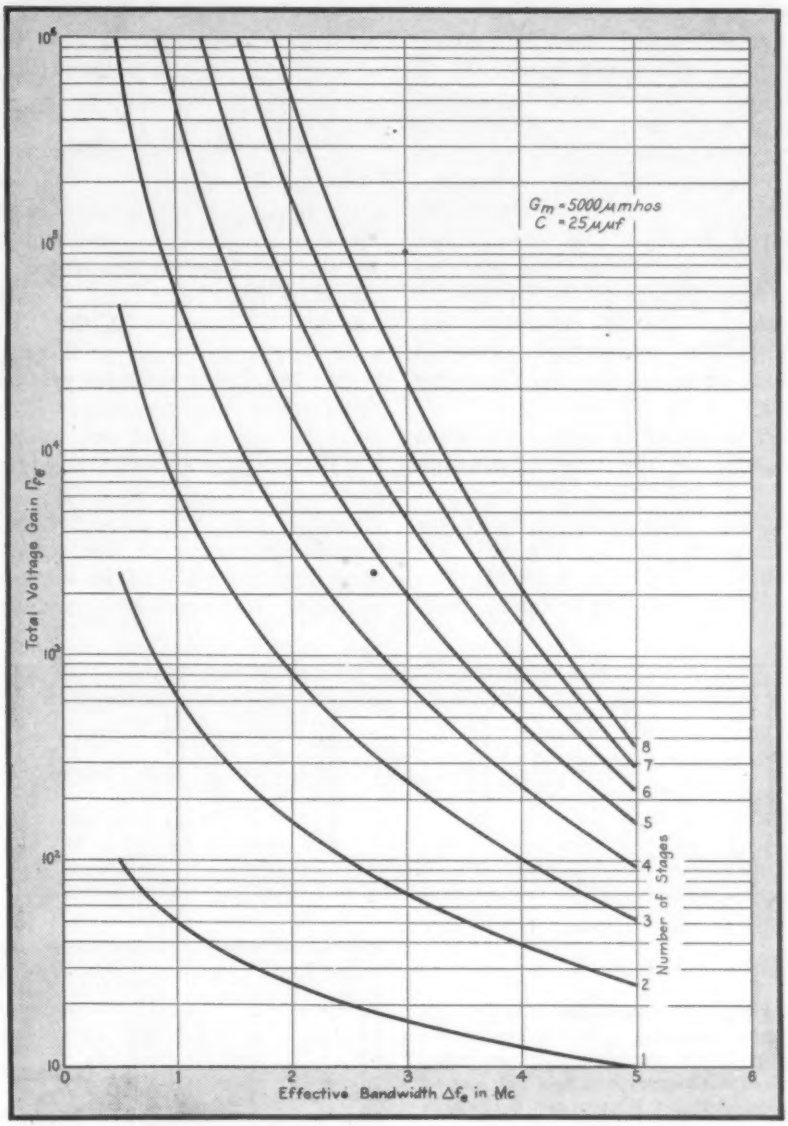


FIG. 7—Design curves for determining the number of amplifier stages required to meet a particular set of design requirements when using single-inductor coupling networks in wide-band amplifiers

TABLE I. AMPLIFIER DATA

Number of Stages (N)	A_s	A_g
1	0.25000	0.15915
2	0.12500	0.10243
3	0.09375	0.08114
4	0.07813	0.06923
5	0.06836	0.06137
6	0.06152	0.05570
7	0.05640	0.05135
8	0.05236	0.04788

$$\Delta f_s = \frac{-N}{\pi RC}\int_{\pi/2}^{0} \sin^2\phi \cos^{2(N-1)}\phi d\phi \quad (5.53)$$

The solution of this integral is direct, but for ease of general expression it is necessary to exclude the case of the single-stage amplifier. For this case $N = 1$ and the integral becomes

$$\Delta f_s = \frac{-1}{\pi RC}\int_{\pi/2}^{0} \sin^2\phi \, d\phi \quad (5.54)$$

The solution to this is immediate and for one stage we have

$$\Delta f_s = 1/4RC \quad (5.55)$$

For more than one stage, the solution of the expression is obtained in the form of a series product. This is because the integration of the Nth power of a trigonometric function is a repeated integral of reduced power. The general solution for the effective bandwidth for more than one stage is

$$\Delta f_s = \frac{N}{16\,RC}\prod_{a=4}^{a=2(N-1)}\left(\frac{a-1}{a+2}\right) \quad (5.56)$$

The above expression is seen to give the effective bandwidth of the amplifier in terms of the number of stages and the circuit constants R and C. The equation can be written

$$\Delta f_s = A_s/RC \quad (5.57)$$

where

$$A_s = \frac{N}{16}\prod_{a=4}^{a=2(N-1)}\left(\frac{a-1}{a+2}\right) \quad (5.60)$$

Now we can evaluate A_s for any number of stages and tabulate it. Then for a particular amplifier, C will be fixed by the circuit layout and type of tube used, but R must be chosen to satisfy the bandwidth requirement.

Table I gives the value of A_s for amplifiers of from one to eight stages. This is seen to be extremely useful for the above-discussed application. Also tabulated in Table I are the values of A_g, which is the constant of bandwidth from Eq. (2.31) for general bandwidth, in which bandwidth is taken as the −3 db response width. For this case we have

$$\Delta f = A_g/RC \quad (5.70)$$

where

$$A_g = \frac{\sqrt{\frac{1}{\alpha^{2/N}} - 1}}{2\pi} \quad (5.71)$$

These values were computed directly by setting $\alpha = 0.707$ and evaluating A_g for values of N from one through eight.

An examination of the two columns in Table I shows that as the number of stages increases, the constants become more nearly equal. This consideration leads to a desirable fact concerning the db down from maximum response at the effective bandwidth of a curve.

Letting Δf_s equal Δf_p we can solve for the relative power response β at the effective bandwidth for any value of N. From Eq. (5.30) and (5.57) we have

TABLE II. AMPLIFIER RESPONSE

Number of Stages (N)	DB down at Δf_s
1	5.399
2	4.163
3	3.886
4	3.757
5	3.683
6	3.633
7	3.605
8	3.570

$$\frac{A_s}{RC} = \frac{\sqrt{\frac{1}{\beta^{1/N}} - 1}}{2\pi RC}$$

The general expression for β in terms of A_s becomes

$$\beta = \left[\frac{1}{1 + (2\pi A_s)^2}\right]^N \quad (5.80)$$

The db down at the effective bandwidth, in terms of A_s for N stages, is then

$$\text{db} = 10N \log_{10}[1 + (2\pi A_s)^2] \quad (5.90)$$

Table II gives the db down response of the amplifier characteristic at the effective bandwidth for one through eight stages. These values are in the anticipated agreement deduced from the values of Table I; that is, as the number of stages increases, the values of effective bandwidth and the 3 db down characteristic become more nearly equal.

The above-considered characteristics of the behavior of the single-inductor coupling network all give valuable yet simple equations for obtaining the design constants of an amplifier for a given set of conditions.

Composite Total Voltage Gain and Effective Bandwidth Behavior for N Stages

A composite relationship can be obtained for the complete behavior of N stages of single-inductor networks in which the total voltage gain, Γ_{fo}, is functional with respect to the effective bandwidth, Δf_s, and the element constants of the networks. This relationship gives the complete design requirements for any amplifier using the two fundamental requirements of total voltage gain and effective bandwidth desired.

From Eq. (1.22) for total gain and Eq. (5.57) for effective bandwidth, we have

$$\Gamma_{fo} = \left(\frac{g_m A_s}{\Delta f_s C}\right)^N \quad (6.10)$$

We see that Γ_{fo} is expressed in terms of the effective bandwidth desired, Δf_s, the effective bandwidth constant A_s (which is known and constant for any number of stages), the g_m of the tube, and the capacitance of the circuit. Thus for some independently chosen value of g_m, and with C fixed by the circuit layout and type of tube used, we have Γ_{fo} expressible in terms of the bandwidth desired and the number of stages.

For purposes of generalization in order to compute the desired family of curves we will arbitrarily assign reasonable values to g_m and C. Letting g_m + 5000 μmhos and C = 25 $\mu\mu$f, we have

$$\Gamma'_{fo} = \left(\frac{200\,A_s}{\Delta f_s}\right)^N \quad (6.11)$$

where Δf_s is expressed in megacycles. Figure 7 is a plot of this equation over the entire practical range of application, with Δf_s covering from 0.5 to 5.0 megacycles and from one through eight stages considered. With this figure one can obtain immediately the number of stages required for a particular set of design requirements.

For any other values of g_m and C in an amplifier the total gain that will be obtained is

$$\Gamma_x = \Gamma'_{fo}\left(\frac{g_{mx}}{5000}\Big/\frac{C_x}{25}\right)^N \quad (6.20)$$

With Square Waves

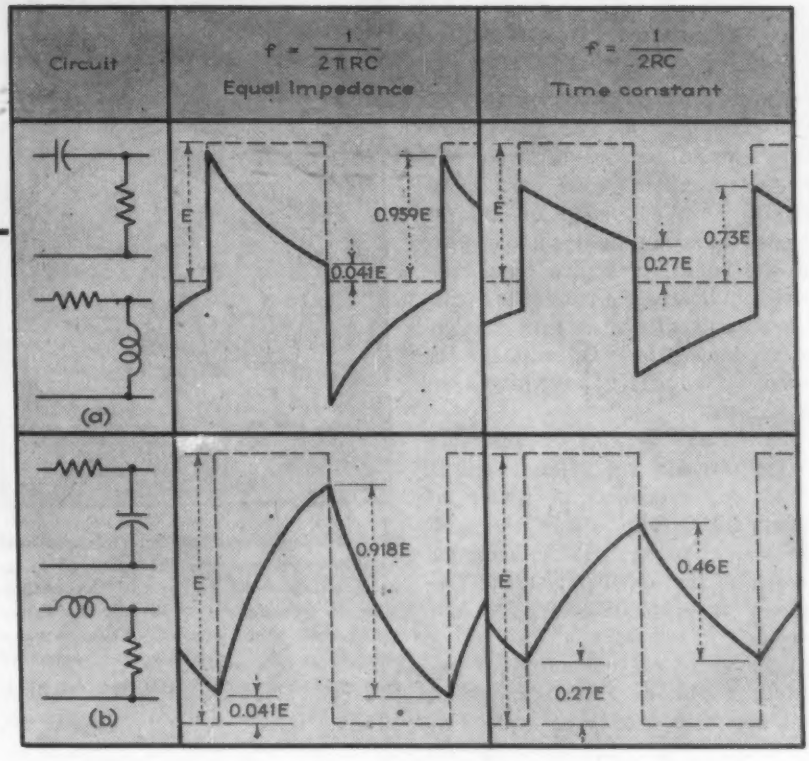


FIG. 3—High-pass (a) and low-pass (b) circuit outputs and inputs are compared for square-wave frequencies of equal impedance and time-constant conditions

or the resistance, as the case may be, has been adjusted so that the output voltage decays to 4.3 percent of its maximum value, the impedance X_c equals the resistance R, or $C = 1/(2\pi fR)$. If the square-wave frequency is that frequency at which information is required, the measurement directly gives $X_c = R$. Because of this relation, the technique is referred to as equal-impedance measurement.

That the specified condition has been reached can readily be observed from the scale on the face of the oscilloscope. If the time base of the oscilloscope is used and it is the frequency which is being varied, it is necessary simultaneously to readjust the sweep rate of the oscilloscope. The oscilloscope trace will be as shown in Fig. 2(b). However, if no sweep is used—just vertical deflection—the trace will be as shown in Fig. 2(c). In addition, the trace can be located on the oscilloscope screen by means of the vertical centering control so as to eliminate most of the lower half of the trace, thereby taking full advantage of the screen size as illustrated in Fig. 2(d).

If resistance is to be measured, the calibrated capacitor is inserted for C and the unknown resistor for R. Resistance is given by $R = 1/(2\pi fC)$.

If inductance is to be measured, the procedure is the same except that the voltage developed across the inductor is applied to the oscilloscope. To make use of the voltage developed across the resistor in measuring inductance, it is necessary to compare it with the applied square-wave voltage in order to observe the equal-impedance condition of Fig. 3(b). This procedure requires an arrangement such as an electronic switch. It has given less reliable results than the preceding method—doubtless because of this added complication. Inductance is given by $L = R/(2\pi f)$.

Time Constant Method

An alternative to the preceding is to use a square wave with a repetition period of $2T$ where T is the time constant of the RL or RC circuit under study. That is, the period of a half cycle of the square wave is adjusted to equal the time constant of the circuit, with the result that by the end of each half cycle the output wave has fallen to 36.8 percent of its initial value. See Fig. 3(a). Capacitance is given by $C = 1/(2\pi fR)$, and inductance by $L = R/(2f)$.

This choice of repetition rate has the advantage of interrupting the decay voltage at a point of greater slope than in the equal-impedance method. Dimensions of the image on the oscilloscope are more sensitive to changes in circuit parameters and hence, as a measuring method, the time-constant repetition rate has an advantage. However, the amplitude of the initial output voltage, as well as the final decay value, changes rapidly with circuit changes—which is not the case if frequencies near the equal-impedance frequency are in use.

Aside from being a source of annoyance during adjustments—it can be compensated for by continuous manipulation of the oscilloscope gain—this is no drawback. As a matter of technique the equal-impedance method may be preferred; it is quicker. But for higher accuracy, justifiable only if the precautions described previously are observed, the time constant method is superior.

With a particular set of equipment, the two methods can be used interchangeably to extend the range over which measurements can be made. For example, if the high-frequency response of the equipment is limited and the calibrated resistance fixed, use of the time

Impedance Measurements

This discussion describes the test equipment and procedures for determining capacitance and inductance, as well as the natural frequency, distributed capacitance, resistance, and Q of inductors, by oscilloscopic observation of square-wave decay rates. Results of actual measurements are given, showing accuracy

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INTEREST in square waves has centered around their utility in indicating the transient reaction and wide-band response of circuits. In addition, square waves can be used to measure impedances by the following method. It employs a minimum of calibrated equipment, is simple in circuit and operation, rapid and, with the precautions described below, is highly accurate.

Advantages of square waves for testing lie in their multiple-frequency content. For example, in determining resonant frequency of a circuit, square-wave response indicates where the resonant frequency lies irrespective of what square-wave test frequency is being used.

On the other hand, the sine-wave response of the circuit will not give an indication until the test frequency has been adjusted approximately to the resonant frequency. Where the resonant frequency is altogether unknown, positive indication obtained from a square wave of any frequency eliminates the time-consuming necessity of hunting for the unknown frequency as in sine-wave testing.[1]

Apparatus Requirements

Equipment needed for square-wave impedance measurements includes a square-wave generator of known frequency, a calibrated or standard impedance, and a cathode-ray oscilloscope. Either the square-wave frequency or the calibrated impedance must be variable (preferably the frequency if it must be one and not the other), but the range over which measurements can be made is greatly extended if both are made variable. Output impedance of the square-wave generator should be at most one-tenth the smallest impedance to be measured. If it is not low enough a cathode follower[2] can be added, as in Fig. 1. The input impedance of the oscilloscope should be at least ten times larger than the largest impedance to be measured. As will be shown, this impedance can be as high as the grid input of a vacuum tube. If inductance or capacitance is to be measured, the calibrated impedance is a resistance. To measure resistance a calibrated capacitor is the more useful although an inductor can be used if necessary.

Consider the circuit of Fig. 2(a). It can be shown by operational analysis that if the generator provides a square wave of frequency $F = 1/(2\pi RC)$, the voltage developed across R is of the form in Fig. 2(b). This voltage across R decays during a half cycle to 0.043 of its initial value. An oscilloscope across R is used to observe this decay of resistor voltage.

When the square-wave frequency

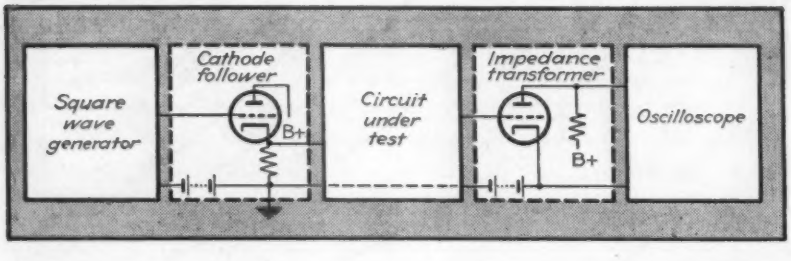

FIG. 1 (left)—Cathode follower decreases output impedance of generator while impedance transformer increases input impedance of oscilloscope in the general set-up of equipment used for square-wave testing

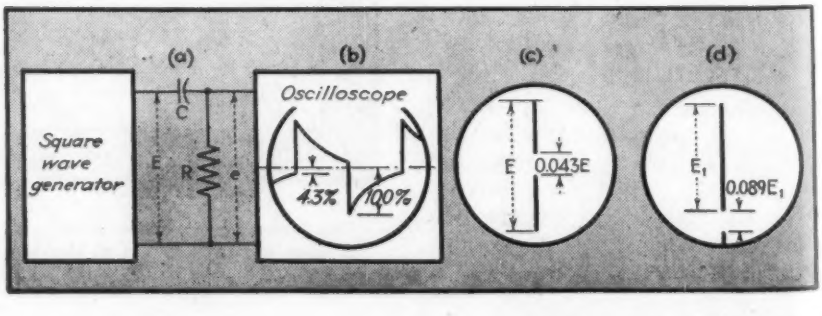

FIG. 2 (right)—Circuit response to a square wave of frequency $1/(2\pi RC)$ follows the law $e = Ee^{t/RC}$ decaying from an initial value of 100 percent to a final value of 4.3 percent as at (b). Without sweep the trace appears as in (c). Moving the trace off center (d) increases the accuracy

Microsecond PULSE GENERATOR

Results of investigation to reduce deionization time of thyratrons used in a circuit providing pulse-type signals of variable duration at high repetition rates

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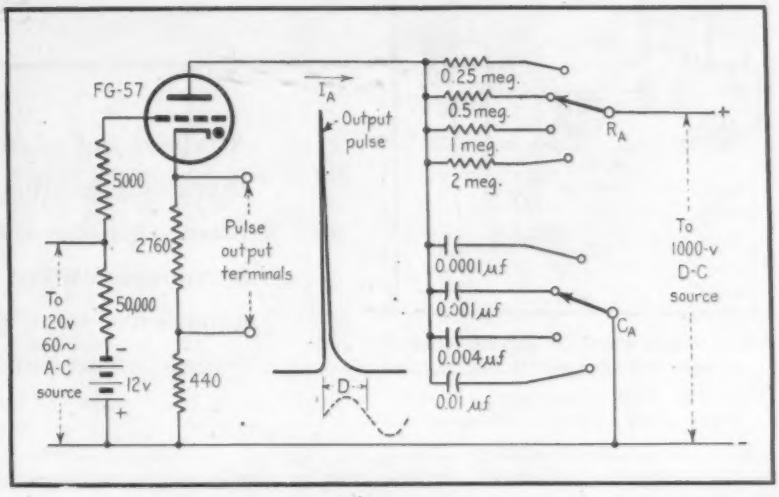

FIG. 1—Circuit used to generate pulses at high repetition rates (up to 400 per sec.), with waveform of output pulse. Performance data is in Table I

ALTHOUGH THE thyratron gas tube has been in common use for some time as a switching or keying device, it has generally been assumed that its repetition rate had definite limitations due to the deionization time of the gas. Several investigators, however, have noted that deionization time does not necessarily limit the operational frequency under all circumstances and modes of operation.

In the course of some development work, a source of pulse-type signals of variable duration and variable repetition rate was required. Manufacturer's data indicated that the ionization time for typical thyratrons varied between 1 and 50 microseconds, and the deionization time did not exceed 1000 microseconds. Since the break-down or ionization time was well within the requirements, it appeared as though the deionization time would be the pertinent factor. One reference stated that this time varied directly with the gas pressure, inversely as the 3/2 power of the grid voltage, and directly as the 0.7 power of the anode current. It was also stated that as a grid-controlled rectifier the device could not be operated above 5000 cycles.

Obviously, little can be done about the gas pressure, which is fixed at the time of manufacture. The other two factors indicate that large grid voltages and low anode currents should be used to get short deionization times.

The basic test circuit arrangement utilized a thyratron to discharge a capacitor which was recharged from a d-c source through a limiting resistor, as in Fig. 1.

Results for an FG-57 thyratron with 60-cps excitation on the grid are given in Table 1, and show that the duration of the pulse is determined solely by the capacitance of the discharging capacitor. After the capacitor value has been lowered to a point where the capacitor can charge to the applied direct voltage, the amplitude of the pulse is proportional to the size of the capacitor.

The pulses were viewed on the screen of a cathode-ray oscilloscope with a super-imposed transparent reference lattice. Pulse duration was evaluated, with any given setting of the sweep, by means of a sine wave of known frequency from an R-C oscillator. The frequency was adjusted until a half sine wave occupied the same number of divisions on the horizontal scale as did the pulse. Knowing the frequency, the time duration of a half cycle could be readily found.

The values for pulse duration in Table 1 include the points from which the pulse trace leaves the horizontal axis and returns to it. In the case of the 9.4-microsecond pulse the 63 percent and 37 percent points were less than 1 microsecond apart.

Repetition rates between 60 and 400 per second were found practical with smaller tubes such as the 884. Adequate shielding from stray fields and from light is recommended for the gas tubes, especially the more sensitive types such as the 2050, 2051 and 2D21.

TABLE I. TEST DATA

C_A in μf	R_A in meg.	I_A(d-c) in ma.	Pulse Duration in μsec	Pulse Peak Voltage in Volts
0.01	0.25	2.3	130.	751
0.01	0.5	1.6	130.	676
0.01	1	0.9	130.	525
0.01	2	0.05	130.	375
0.004	0.25	2.2	97.5	751
0.004	0.5	1.5	97.5	751
0.004	1	0.8	97.5	638
0.004	2	0.05	97.5	488
0.001	0.25	0.04	18.7	488
0.001	0.5	1.2	18.7	488
0.001	1	0.6	18.7	488
0.001	2	0.3	18.7	488
0.0005	0.25	1.9*	13.1	300
0.0005	0.5	1.2*	13.1	300
0.0005	1	0.5*	13.1	300
0.0005	2	0.3*	13.1	300
0.0001	0.25	2.2*	9.4	150
0.0001	0.5	1.2*	9.4	150
0.0001	1	0.6*	9.4	150
0.0001	2	0.3*	9.4	150

* The a-c grid voltage was changed from 120 to 115 volts for the last eight sets of readings.

constant method will permit measuring capacitors π times as large as could be measured by the equal-impedance rate.

Extensions of the Method

It is conceivable that other repetition rates could be used. The two frequencies mentioned have been chosen because of their particular significance in circuit analysis. One extension of the response analysis to a square wave of the equal-impedance frequency, which indicates the reason for making measurements at this particular frequency, is in determining the cut-off frequencies of filters or amplifiers.

Cut-off frequencies of communication circuits are often taken in sinusoidal analysis as those at which the output is half the mid-frequency power. This condition occurs at the equal-impedance frequency in simple *RL* and *RC* networks.

Because of the cascading of impedances and the use of compensation networks, the decay curves of communication circuits will no longer be simple exponentials, as in Fig. 3. However, the square-wave frequency at which the output decays to 4.3 percent of its initial value can still be taken as the low cut-off frequency. Thus the equal-impedance method can be used to measure low cut-off frequencies of complex circuits. A similar extension of the method can be made to measure high cut-off frequencies.

Caution must be used in making this extension because it is the deviation from the exponential curve which reveals most about communication circuits. This method only considers the information obtainable from the end points of the circuit response to square waves. Similar use can, with reservations, be made of the time constant method, and to measure high-frequency cutoff.

Measurement of Q Factor

Inductors, because of their distributed capacitances, have self-resonant frequencies above which they behave as capacitors. In choosing chokes and transformers, it is necessary to know not only their inductances, but also the frequency ranges over which they are inductive. By square-wave measurement, the self-resonant frequency of an inductor and its resonant Q can be determined.

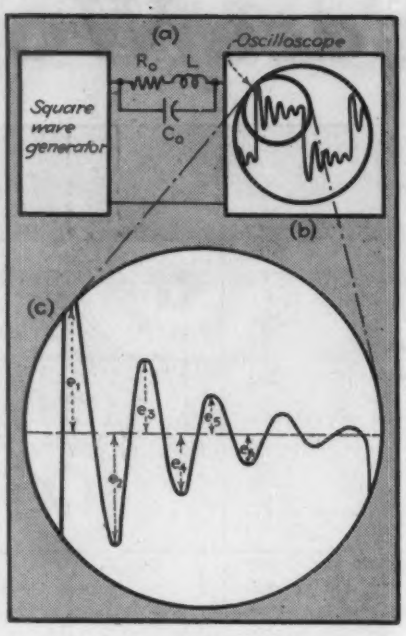

FIG. 4—Equivalent inductor circuit (a) and square-wave response (b) enlarged in (c) from which come values for determining: Natural frequency $f_o = nF$, where n is the number of cycles per cycle of square wave and F is the square-wave frequency; $R_o = 2Lf_o \log_\epsilon (e_2/e_3)$; $C_o = 1/[(2\pi f_o)^2 L]$; and $Q_o = \pi/\log_\epsilon (e_2/e_3)$

The reactance of the inductor is measured by the previous technique. The inductor is then connected between the high sides of the square-wave generator and the oscilloscope; the low sides of the instruments are directly connected as in Fig. 4(a).

When excited by the multiple-frequency transient of the square wave, the inductor oscillates at its natural period with the result that there is a damped sine wave superimposed on the square wave which is being applied to the oscilloscope through the inductor, Fig. 4(b). The number of oscillations per cycle of the square wave, times the square-wave frequency, gives the natural frequency (f_o) of the inductor.

The square-wave frequency should be adjusted so that a whole number of cycles appears on each cycle of the square wave because counting fractions is difficult. Also, the square-wave frequency should be considerably lower (one-tenth is a convenient ratio) than the natural frequency of the inductor. This is partly because, as the square-wave frequency approaches the self-resonant frequency of the inductor, it forces the oscillations to the extent of changing their frequency, and partly because, with but a few cycles of oscillation per cycle of square wave, errors in estimating fractions or in observing when there are none, increase.

There is no gain in using a square-wave frequency lower than one-twentieth f_o because of the large number of cycles-per-square-wave which must then be counted. The half period of the lowest square wave that can be used must be no longer than the oscillation decay time of the self-resonant inductor.

The rate of decay of the oscillation is used to measure the a-c resistance of the inductor at its natural frequency. Because the impedance of the inductor at its resonant frequency is more dependent upon the Q of the inductor in this range than it is upon the simple inductance, the coil resistance at the natural frequency (R_o) is of greater significance at the upper frequency limit of usability.

This method is illustrated in Fig. 4(c). Transformers can be treated as combinations of self and mutual inductances, each having its own natural frequency and apparent a-c resistance. Critical damping can be quickly determined by this same method. Resonant circuits of all types can likewise be measured.

Neutralizing Impedance Effects

The input impedance of the oscilloscope reduces the shunt-arm impedance while the output impedance of the square-wave generator increases the series-arm impedance of the test circuit. Rather than attempt to correct analytically for these impedances, which can well be complex, it is better to remove their effect, especially since to do so is easy.

Reducing the output impedance of the square-wave generator by means of a cathode follower has been discussed. If the output impedance of the square-wave generator has a d-c path, as it will if a cathode follower is used, all the foregoing circuits provide d-c grid returns. Therefore, an impedance

(*Continued on page* 336)

FILTER D
For Grid- C

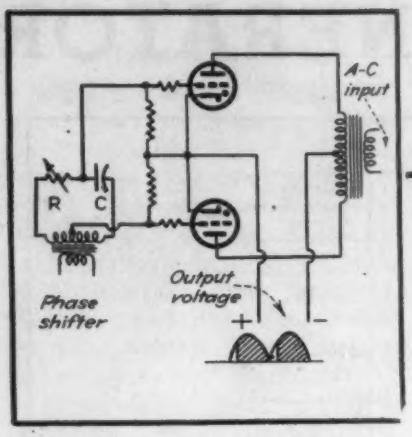

FIG. 1—Basic circuit of grid-controlled rectifier with phase-shift control

Analysis of voltage waves in single-phase thyratron rectifier circuits with inductive-input filters, taking into account the variations in harmonic content with conduction angle. Basic equations are developed into a practical design procedure, and examples are given

SINGLE-PHASE full-wave rectifiers employing gas triodes (thyratrons) have bee nused in numerous applications where accurate and smooth control of the direct-current output is required. In some of these applications adequate filtering is necessary to reduce the output ripple voltage below some specified value. The usual filter design equations used in the case of the high-vacuum or gas-diode rectifiers are not suitable because the magnitudes of the harmonic components to be filtered vary with the conduction angle of the tube.

Grid-controlled gas-tube rectifiers are usually controlled by means of a phase-shifting circuit that controls the point on the anode voltage wave at which the tube starts to conduct.

Rectifier with Resistance Load and No Filter

In Fig. 1 is shown a typical grid-controlled rectifier and phase-shifting circuit for controlling the conduction angle, with an illustration of the type of output voltage wave to be expected for a given angle of delay if the load is pure resistance. The action of the gas triodes and phase shifter circuit will not be discussed further as this is usually dealt with in most texts on electronics, but rather, an analysis of the voltage waves and the design of filters for these waves will be considered in this paper.

In Fig. 2 is shown a typical output voltage wave in which the firing of the tube has been delayed for an angle ϕ and tube conduction takes place through an angle $\theta = \pi - \phi$ if the arc drop is assumed negligible. This recurring wave may be expressed by a Fourier series in the usual manner:

$$e = E_{dc} + \sum_{n=1}^{n=\infty} A_n \cos nx + \sum_{n=1}^{n=\infty} B_n \sin nx \quad (1)$$

where

$$E_{dc} = \frac{1}{2\pi}\int_0^{2\pi} f(x)\,dx \quad (2)$$

$$A_n = \frac{1}{\pi}\int_0^{2\pi} f(x)\cos nx\,dx \quad (3)$$

and

$$B_n = \frac{1}{\pi}\int_0^{2\pi} f(x)\sin nx\,dx \quad (4)$$

In the case of the wave shown in Fig. 2, $f(x)\Big]_0^{\phi} = 0$ and $f(x)\Big]_{\phi}^{\pi} = E_{max}\sin x$ where $x = \omega t$ and E_{max} is the crest value of the transformer voltage from one end to center tap. In determining the coefficients A_n, B_n and E_{dc} it will be necessary to integrate only through the limits from ϕ to π and multiply the result by two since the half-cycles are identical. Then

$$E_{dc} = \frac{E_{max}}{\pi}\int_{\phi}^{\pi}\sin x\,dx = \frac{E_{max}}{\pi}\left(1 + \cos\phi\right) \quad (5)$$

The direct current component of the voltage wave thus varies from zero to the value $2E_{max}/\pi$ as the delay angle is varied from π to zero. Figure 3 shows how the ratio E_{dc}/E_{max} varies with ϕ.

Since it is usually necessary to know only the magnitude of the harmonic terms present, a complete Fourier series for the wave is not necessary. Inspection of Eq. (1) will show that the nth harmonic is given by $(A_n \cos nx + B_n \sin nx)$, and therefore the magnitude of the nth harmonic voltage is $E_{n\ max} = A_n + jB_n$. Substituting Eq. (3) and (4) in Eq. (6),

$$E_{n\ max} = \frac{1}{\pi}\int_0^{2\pi} f(x)\,(\cos nx + j\sin nx)\,dx$$

$$= \frac{1}{\pi}\int_0^{2\pi} f(x)\,e^{jnx}dx \quad (7)$$

Putting in for $f(x)$ its value for the particular wave under study and changing the limits, we get

$$E_{n\ max} = \frac{2E_{max}}{\pi}\int_{\phi}^{\pi}\sin x\,e^{jnx}dx$$

$$= \frac{-2E_{max}}{\pi}\left[\frac{e^{jnx}\,(\cos x - jn\sin x)}{1-n^2}\right]_{\phi}^{\pi} \quad (8)$$

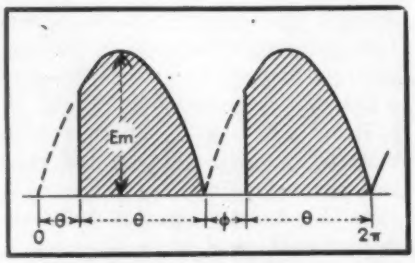

FIG. 2—Wave form for grid-controlled rectifier with no filter

DESIGN Controlled Rectifiers

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By applying the principle of symmetry to the wave, it may be seen that $f(x) = f(\pi + x)$, for which it can be shown that no odd harmonics can exist. If n is given only even values, the limits substituted and the resulting equation expanded, the following expression for the crest value of the nth harmonic voltage results:

$$E_{n\,max} = \frac{2\,E_{max}}{\pi\,(1-n^2)} \sqrt{(1+\cos\phi\cos n\phi + n\sin\phi\sin n\phi)^2 + (n\sin\phi\cos n\phi - \cos\phi\sin n\phi)^2} \quad (9)$$

Figure 3 shows the variation of the second and fourth harmonic terms with the angle ϕ. It must be stressed that the curve shown in Fig. 3 can be used only with a non-reactive load as the presence of a filter changes the output voltage wave of the rectifier considerably. This fact is commonly overlooked, as has been pointed out by M. B. Stout.[1]

Rectifier with Inductive-Input Filter

It was noticed in Fig. 2 that current flows for only a portion of each half-cycle if the load is non-inductive. If a series inductance is added, the current will tend to flow for a longer period of time but with a corresponding decrease in the peak value. If the inductance is made large enough, current will flow through the load circuit continuously. A critical value of inductance L_{cr} may be defined as that value which will just prevent the current from dropping to zero at any portion of the cycle.

If a grid-controlled rectifier with delayed firing angle has an inductive-input filter (Fig. 4) with the value of the inductance less than critical, damped oscillatory waves are set up as shown in Fig. 5(a), and the circuit in general becomes very unstable. This type of operation is very undesirable and should be avoided by making $L > L_{cr}$ for all values of load current and delay angle.

If $L > L_{cr}$, the tube that is conducting will continue to conduct until the second tube fires, even though the anode potential swings negative with respect to the transformer center-tap over a portion of the cycle as shown in Fig. 5(b). This effect is produced by the induced emf of the input filter choke.

Since for this case the tube drop is constant throughout the whole cycle, it will not enter into the calculation of the harmonic terms and can be subtracted from the direct-current component.

A study of the wave in Fig. 5(b) will show that $f(x) = E_{max}\sin x - E_D\Big]_{\phi}^{\pi+\phi}$ Substituting this in Eq. (2) gives

$$E_{dc} = \frac{E_{max}}{\pi}\int_{\phi}^{\pi+\phi}\sin x\,dx - \frac{E_D}{\pi}\int_{\phi}^{\pi+\phi}dx = \frac{2\,E_{max}}{\pi}\cos\phi - E_D \quad (10)$$

A plot of Eq. (10), neglecting tube drop, is shown in Fig. 6. It is seen that the complete range of output voltage may be covered with only a 90-deg variation of delay angle. Values from this curve should be multiplied by $E_{dc}/(E_D + E_{dc})$ to correct for tube drop.

Substituting $f(x)$ into Eq. (7) gives for the nth harmonic

$$E_{n\,max} = \frac{2\,E_{max}}{\pi}\int_{\phi}^{\pi+\phi}\sin x\,e^{jnx}\,dx \quad (11)$$

which when integrated, limits substituted, and reduced as before (with $n = 2, 4, 6, \ldots\ldots$) gives

$$E_{n\,max} = \frac{4\,E_{max}}{(1-n^2)} \sqrt{(\cos\phi\cos n\phi + n\sin\phi\sin n\phi)^2 + (\cos\phi\sin n\phi - n\sin\phi\cos n\phi)^2} \quad (12)$$

Since any filter designed to reduce the second harmonic voltage to a specified value will be at least four times more effective for the next higher harmonic, it is necessary to consider only the second harmonic in the design of the filter. Figure 6 shows the variation of the second harmonic voltage at the input to the filter with the delay angle ϕ.

The usual procedure for determining the critical value of inductance required in single-phase full-wave diode rectifier circuits is to neglect all the harmonic terms except the second and solve the resulting equivalent circuit for the direct and alternating components of current through the input choke. The critical value of inductance L_{cr} which will just keep a current flow at all times through the choke can then be determined from the critical condition of $I_{dc} = I_{ac\,max}$. This solution[2] gives $L_{cr} = R_T/1130$ for a 60-cycle impressed voltage, where R_T is the total d-c resistance that the direct component of cur-

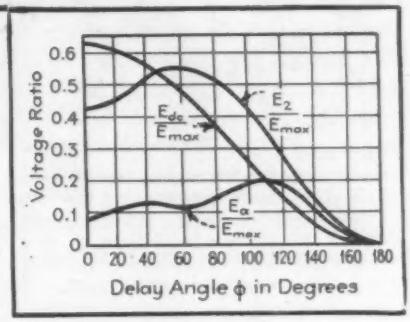

FIG. 3—Output components of α grid-controlled rectifier with no filter

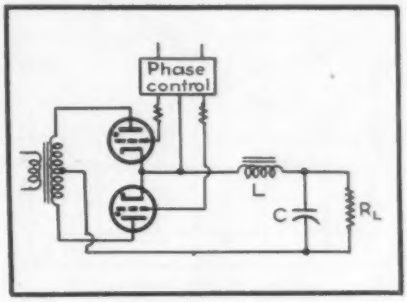

FIG. 4—Grid-controlled rectifier circuit with inductive-input filter

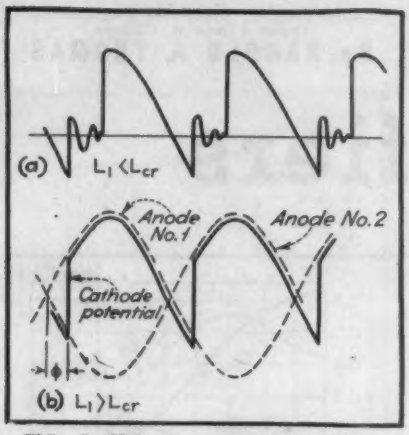

FIG. 5—Voltage waves for grid-controlled rectifier with inductive-input filter. At (a) the inductance is less than the critical value, and at (b) it is greater than the critical value

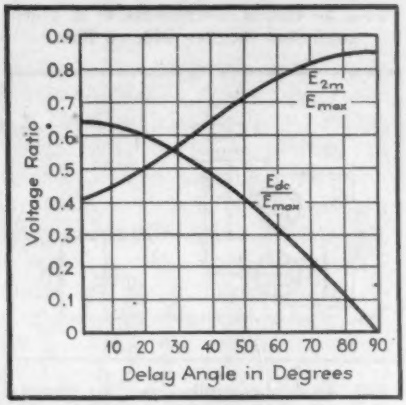

FIG. 6—Output components of grid-controlled rectifier with inductive-input filter

rent must flow through. This equation is correct within about 10 percent for the diode rectifiers except when operating at low voltages, but will give an error of from 25 to 50 percent, depending on the delay angle, for the grid-controlled rectifier. The correct value of critical inductance for grid-controlled rectifiers for different firing angles has been determined in an analysis by Overbeck.[3] The results of this investigation are shown in the curve of L_{cr}/R_T versus ϕ in Fig. 7. The values of L_{cr}/R_T should be multiplied by $(E_D/E_{dc}) + 1$ to correct for tube drop.

As mentioned before, the a-c voltages of higher order are not only much smaller initially than the second harmonic but also are attenuated by the filter to a much higher degree, and therefore the percent output ripple voltage of the filter may be defined as the rms value of the second harmonic output voltage expressed as a percentage of the d-c output voltage. Then

$$\% \text{ Ripple} = 100 \times E_2/E_{dc\ output} \quad (13)$$

$$E_2 = 4\ E_{max}\ K_\phi\ S/3\pi\sqrt{2} \quad (14)$$

where

$$K_\phi = \sqrt{(\cos\phi \cos n\phi + n \sin\phi \sin n\phi)^2 + (\cos\phi \sin n\phi - n \sin\phi \cos n\phi)^2}$$

and S, the smoothing factor of the filter, is in accordance with the usual filter design equation

$$S = \frac{1}{(2\omega)^{2a}\,(L_1L_2L_3 \ldots L_a)\,(C_1C_2C_3 \ldots C_a)} \quad (15)$$

ω being 2π times the original supply frequency and a the number of sections in the filter.

The direct output voltage is the direct input voltage to the filter minus the voltage drop in the filter:

$$E_{dc\ out} = \left(\frac{2\ E_{max}}{\pi}\cos\phi - E_D\right) - I_{dc}\,R_F \quad (16)$$

and

$$I_{dc} = \frac{\left(\frac{2E_{max}}{\pi}\cos\phi - E_D\right)}{R_L + R_F} \quad (17)$$

where R_L is the resistance of the load and R_F is the filter resistance. Substituting Eq. (17) into (16), then substituting the resulting equation along with Eq. (14) into (13) gives

$$\% \text{ Ripple} = \frac{4\ E_{max}\ K_\phi\ S \times 100}{3\pi\sqrt{2}\left(\frac{2\ E_{max}}{\pi}\cos\phi - E_D\right)\left(1 - \frac{R_F}{R_L + R_F}\right)} \quad (18)$$

In the case of rectifiers for voltages of the order of a few hundred volts or more and for delay angles up to 60 or 70 deg (larger angles than this are impractical), E_D in Eq. (18) may be neglected. Further, since $R_L >> R_F$, the quantity $1 - R_F/(R_L + R_F)$ of Eq. (18) will be approximately equal to 1 (this approximation can be corrected for later), then Eq. (18) can be reduced to

$$\% \text{ Ripple} \cong \frac{\sqrt{2}\,K_\phi\,S \times 100}{3\cos\phi} \quad (19)$$

For a single-section filter at 60 cps, Eq. (19) can be expressed as

$$\% \text{ Ripple} \times L_1C_1 \times 10^{-2} = 0.831\ K_\phi/\cos\phi \quad (20)$$

and for a two-section filter

$$\% \text{ Ripple} \times L_1L_2C_1C_2 \times 10^{-2} = 1.46\ K_\phi/\cos\phi \quad (21)$$

A plot of Eq. (20) and (21) which may be used for design purposes is shown in Fig. 7. If the d-c resistance R_F of the filter chokes is not small compared to R_L, then the values of percent ripple (L_1C_1) should be multiplied by $(R_L + R_F)/R_L$.

Practical Design Procedure

Ordinarily in the design of rectifier and filter systems the output voltage, current rating, and percent ripple that can be tolerated are specified by the use to which the rectifier is to be put, and it is the problem of the designer to choose circuit elements that will allow the specifications to be met in the most economical way. Unfortunately, when starting with the output or load requirements some cut-and-try calculations may be necessary, though the use of the curves in Fig. 6 and 7 will reduce the amount of work quite appreciably. Also, single-phase rectifiers are used only on relatively low-power installations where high accuracy in the design is not usually necessary.

While the equations predict that the output voltage can be varied from a maximum value down to zero, it is obvious from a study of Fig. 6 and 7 that it would require an infinite filter to do so if low percentage ripple is to be maintained. Practical limits on the maximum delay angle range between 60 to 70 deg. At 70 deg the output voltage will be reduced to about 34 percent of the value with zero delay.

The use of a swinging choke for the input inductance will reduce the cost of the filter considerably. Also, since the percent ripple increases with delay angle, the required LC product should be calculated for the largest delay angle. The following examples illustrate the design procedure for a typical rectifier.

Examples

Assume the load requirements are such that the load voltage is to vary between 500 and 1000 volts with a maximum percent ripple of 0.5 percent, and that the load current is to vary between 100 and 500 milliamperes. Neglecting tube and filter voltage drop as a first approximation, we find from Fig. 6 that $E_{dc}/E_{max} = 0.636$ (for $\phi = 0$), or $E_{max} = 1000/0.636 = 1570$ volts. From Eq. (10), $\cos\phi_{max} = 500\pi/2\times1570 = 0.5$, and $\phi_{max} = 60°$.

From Fig. 7, for $\phi = 0$, $(L_{cr}/R_T) \times 10^3 = 0.88$. Since $R_T \cong 1000/$

$100 \times 10^{-3} = 10{,}000$ ohms, then $L_{cr} = 8.8$ henrys. For $\phi = 60°$, $(L_{cr}/R_T) \times 10^3 = 4.4$. Here $R_T = 500/100 \times 10^{-3} = 5000$ ohms, and $L_{cr} = 5000 \times 4.4 \times 10^{-3} = 22$ henrys. Hence the input inductance should have a minimum inductance of 22 henrys at a current of 100 milliamperes.

The amount of filtering necessary should always be calculated for the maximum delay angle. From Fig. 7, for $\phi = 60°$, percent ripple $\times$ $(L_1L_2C_1C_2) \times 10^{-2} = 5.26$. For 0.5 percent ripple, $(L_1L_2C_1C_2) = 1052$. If L_1 is a swinging choke having 25 henrys at 100 milliamperes and 6 henrys at 500 milliamperes, and if C_1 and C_2 are 4 μf each, then $L_2 = 1052/6 \times 4 \times 4 = 11$ henrys. In this case a single-section filter would have proved impractical because of the large values of L and C required.

Since the inductance values of the chokes are now known, their resistances may be determined from the choke design. Typical values for the above chokes rated at 500 milliamperes would be about 75 ohms each. Hence the voltage drop in the filter would be $2 \times 75 \times 0.5 = 75$ volts. Assuming the tube drop is 10 volts, the actual transformer voltage required would be $(1000 + 75 + 10)/0.636\sqrt{2} = 1205$ volts effective each side of center-tap.

In the above example the effect of ignition voltage on minimum delay-angle and two other corrections mentioned earlier in the discussion were not considered because of their small effect. However, in the case of low-voltage high-current rectifiers, these corrections would have to be made and so for the purpose of illustration they will be calculated for the above rectifier.

It will be noticed from Fig. 5(b) that the cathode-anode potential difference is equal to twice the transformer voltage at the instant of firing, and hence the minimum value of ϕ is the value that will make twice the instanteous transformer voltage equal to the ignition voltage of the tube. If FG-17 type thyratron tubes are used in the above application, the ignition potential will be approximately 40 volts. Hence $40 = 2E_{max} \sin \phi_{min}$, and also from Eq. (10) (include the filter drop which was determined from the first approximate design), $1000 + 0.5 \times 2 \times 75 = (2E_{max}/\pi)(\cos \phi_{min} - 10)$. Therefore $\tan \phi_{min} = 40/1085\pi = 0.00172$, or $\phi_{min} = 1°$ and $E_{max} = 1085\pi/2 \cos 1° = 1705$ volts. Also, $E = 1705/\sqrt{2} = 1205$ volts, which is the full-load voltage rating of the transformer secondary from end to center-tap.

To calculate ϕ_{max} from Eq. (10), $500 + 0.5 \times 2 \times 75 + 10 = (2 \times 1705/\pi) \cos \phi_{max}$, from which $\phi_{max} = 57.2°$. Then from Fig. 7, applying corrections, $(L_{cr}/R_T) \times 10^3 = 4.24$ $(1 + 10/500) = 4.33$, and $R_T = (500/100 \times 10^{-3}) + 150 = 5150$ ohms. Therefore $L_{cr} = 4.33 \times 10^{-3} \times 5150 = 22.3$ henrys. Also from Fig. 7 for $\phi_{max} = 57.2°$, percent ripple $\times$ $(L_1L_2C_1C_2) \times 10^{-2} = 4.7$ $(R_L + R_F)/R_L$, and $(R_L + R_F)/R_L = (1000 + 150)/1000$ since this correction should be calculated for the lowest load resistance possible for ϕ_{max}, i.e., for $R_L = 500/0.5 = 1000$ ohms. Then $L_1L_2C_1C_2 = 1080$ for 0.5 percent ripple.

As before, if L_1 is a 25-6 henry swinging choke and C_1 and C_2 are each 4 μf, then $L_2 = 1080/6 \times 4 \times 4 = 11.25$ henrys.

It can be seen that in this example the more exact calculation gave practically the same solution as the approximate design based upon the curves with no corrections except that for the transformer voltage. In low-voltage power supplies, however, it would be well to make an approximate solution from the curves, find the approximate value of R_F and then recalculate the values as was done above.

The curves and design procedure have been checked experimentally and were found to be correct within the limits of experimental error.

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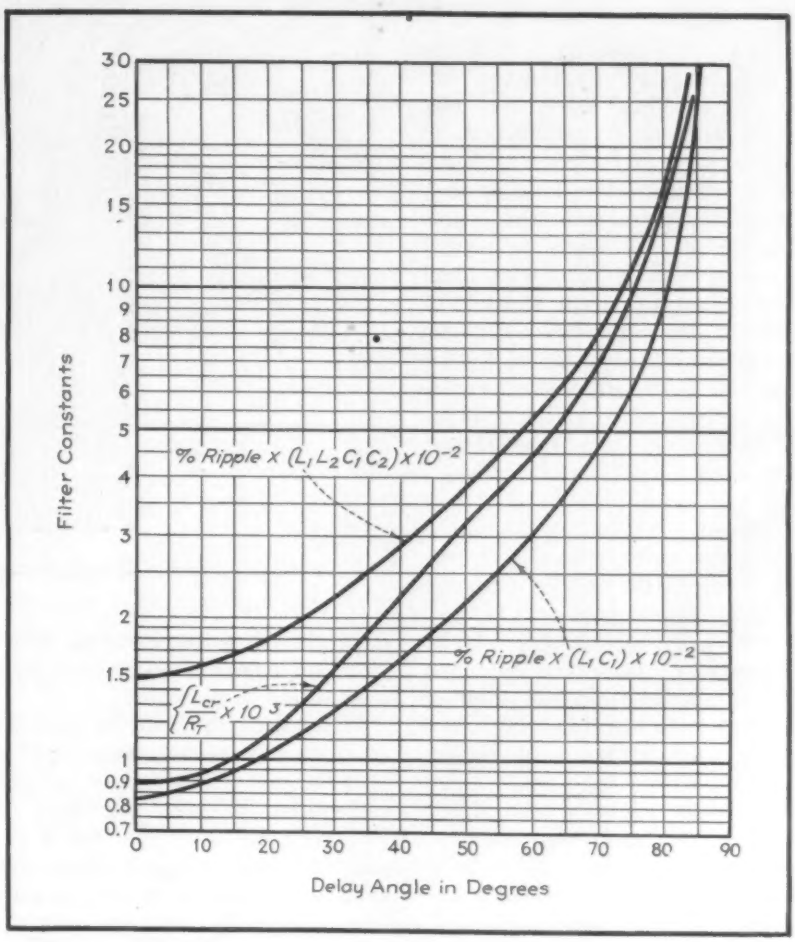
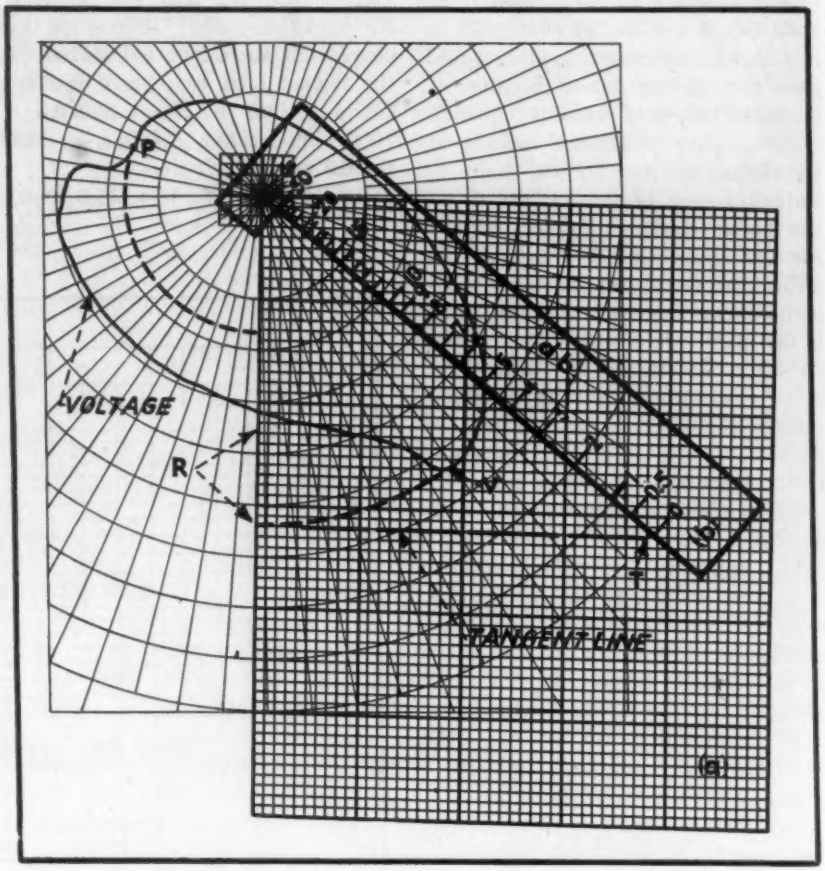


FIG. 7—Curves for determining filter constants for grid-controlled rectifiers

Voltage / db
CONVERSION DEVICE

Linear polar-coordinate graphs are readily interpreted. Plotted data need not be normalized and the size of the time-saver is flexible. An antenna radiation problem is worked out as an example

By EDWIN DYKE
Lear Avia, Inc.
Grand Rapids, Mich.



POLAR-COORDINATE GRAPHS following any fixed E^n law may be readily interpreted in terms of db by means of the two-piece transparent plastic conversion device illustrated.

The function of piece (a) is to set up a proportionality between the db scale of piece (b) and the plotted graph. Thus the graph need not be normalized and the size of the two parts of the conversion device is immaterial so long as they are large enough to fit the graph. Piece (a) can be made up readily by ruling squares (any convenient size) on a transparent sheet. For piece (b), the scale shown here can be transferred to a strip of similar material. Two successive photographic negatives of an ink drawing will yield an excellent transparency, often called an "Ozalid transparency.

Suppose, for example, that a linear-voltage antenna radiation pattern (such as the one shown here) drawn to polar coordinates is to be converted. Piece (a) of the device is oriented by centering its upper left-hand corner over the center of the graph with the aid of a pin, and is then rotated to any convenient position.

The vector of maximum amplitude is selected as a reference point V and, with the aid of the nearest arc on the graph, is traced to one edge of piece (a) as shown at R. This edge of piece (a) is now a fixed reference line. At the reference line the arc is tangent to a horizontal line on piece (a).

With piece (a) held in position as described above, piece (b) is oriented by centering its infinity calibration (∞) over the center of the graph, again with the aid of the pin, and then rotating piece (b) until 0 db intersects the tangent line at point T.

The db equivalent of any voltage point on the graph may now be read on the db scale of piece (b). As shown here, for instance, the db equivalent of point P is determined by following an arc to the vertical reference line R, following a horizontal tangent line from that point to the calibrated edge of piece (b) and reading -7.5 db. The same curve plotted in power would yield for the point P, -3.75 db, obtained by dividing the answer by 2.

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INDUSTRIAL CONTROL

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Dielectric Heating of Tire Cord Sets Twist

TWIST-SETTING of textile yarns with electronic heating is being accomplished by Industrial Rayon Corp. in a new process invented by the company's technical staff.

The twist of the rayon tire cord is set by submitting packages of the cord to dielectric heating. Heat generated in the cord is distributed so uniformly that spools or cones containing 18 pounds or more of rayon tire cord may be effectively treated. Such giant cones are used in the weftless method of tire construction.

The process is completed in a matter of minutes and results in the production of a cord in which the twist is uniformly set. Control of the moisture content of the cord may be facilitated by wrapping the cones of cord in moistureproof paper before processing.

The equipment originally installed for this process has been in operation at Industrial Rayon's Cleveland plant for more than eight months and includes high frequency power generating units having outputs of approximately 22,500 BTU per hour each. They were furnished by the Girdler Corp., through its Thermex Division, and each unit is capable of handling several thousand pounds of packaged tire cord in a 24 hour period. Additional high-frequency twist-setting units are to be installed in two other plants.

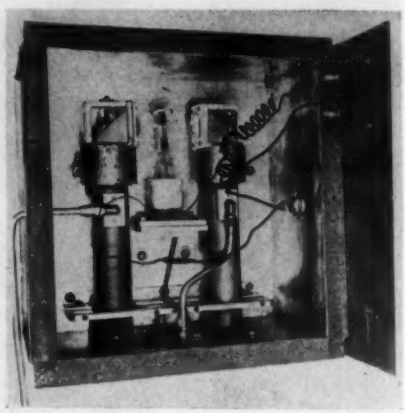
Patent applications covering the use of high-frequency heating for twist-setting of textile products generally, including tire cord, have been assigned to Industrial Rayon. The new process is also being used by The B. F. Goodrich Company, under license from Industrial Rayon, in connection with production of rayon tire cord. Radio Corporation of America supplied the high frequency power units used by Goodrich.

Factory layout of dielectric heating equipment used for setting the twist of rayon tire cord. The 18-lb spools of cord are wrapped in moistureproof paper for control of moisture. The operator at the right is removing plywood covers that were placed over the spools during passage through the heating chambers

Rapid Gas Analysis for Vapor Control

MANY INDUSTRIES are concerned with the problem of controlling contaminated atmospheres. Elaborate air-conditioning systems, special section hoods, etc., are employed in plants to draw off vapors and gases and in many instances workers wear gas masks during certain operations. In spite of these precautions, it is usually necessary to make periodic checks of the air in various parts of the plant to determine whether the concentration of the volatile substance is being held within the safety level.

Most gas analyzers require 15 minutes or more to take an air sample and show only the average concentration of the gas during that period of time. With this technique, momentary high peaks escape



The carbon disulfide analyzer contains a mercury lamp with glass envelope removed and mounted so that its radiation is reflected down absorption tubes to photocells. The contaminated air is also supplied to one tube, then passed through activated charcoal and fed to the second tube for comparison

observation. An electronic instrument developed at E. I. du Pont de Nemours can run continuous samples and give direct and instantaneous readings. This permits accurate second-by-second observation of the vapor level in each step of a manufacturing process.

V. F. Hanson, of the Electrochemicals Department of the du Pont Company, designed the original instrument. A modified model, intended particularly for carbon disulfide analysis, has been developed by Dr. Shirleigh Silverman, assisted by Dr. J. W. Ballou and W. H. Warhus, all of the Rayon

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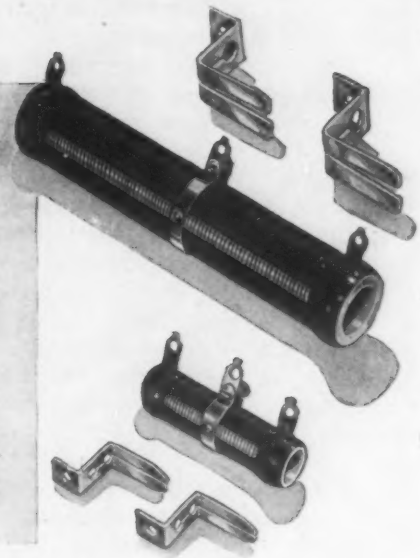

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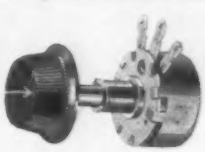

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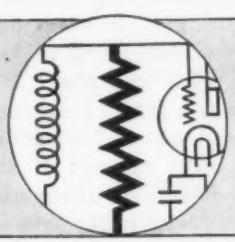

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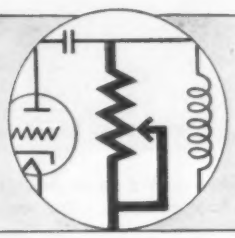


Technical Division of the company. The Mine Safety Appliance Co. is planning to manufacture instruments of this general type.

Operation of the ultraviolet photometer is based on the phenomenon of light absorption by gases. Most gases absorb light of some particular wavelength, in effect casting a shadow where that particular wavelength line would otherwise have fallen. In a spectrum that shadow is known as an absorption line. Carbon disulfide, for example, strongly absorbs light having a wavelength of 3132 Angstrom units, in the ultraviolet range.

Comparison System

The instrument is so constructed that the air to be analyzed is pumped through several small chambers, which filter out dust, oil and moisture, and thence into a pair of parallel tubes, about 31 inches long. The contaminated air runs into the first tube and then through a canister of activated charcoal which removes carbon disulfide, and passes purified air into the second tube. This permits a continuous comparison of the purified with the contaminated air and very minute differences may be detected.

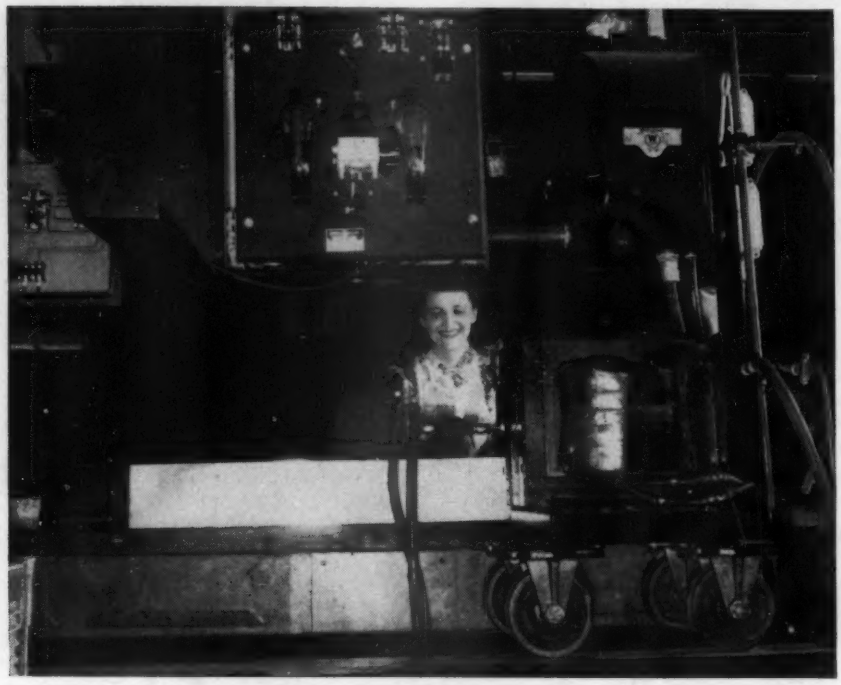
Engineers in the Du Pont plant check on the efficiency of a large suction hose used to draw off fumes during a production process. The intake hose of the analyzer is held at the operator's nose level

Rays of ultraviolet light from a mercury lamp pass through the two tubes and fall upon a sodium phototube mounted at the opposite end of each tube. A vacuum-tube amplifier follows the phototubes and actuates a microammeter for readings.

Filters in the optical system have been so selected that about 60 percent of the photometric response of the cell is due to light of 3132 Angstrom units in wavelength, the light which carbon disulfide absorbs. No other atmospheric element has been found in plants where this instrument is used that absorbs either this band of light or the 3650 Angstrom unit band, which accounts for most of the remainder of the photocell's response. One part of carbon disulfide in a million parts of air will produce an absorption of 0.02 percent.

In one test, 61 readings were made during the nine minutes required to open, dump and clean out a large vessel in which material was treated with carbon disulfide. During most of the operation the concentration of gas remained below 20 parts per million and older methods of analysis, which could give only the average for this entire time interval, would show no danger points. However, the ultraviolet photometer revealed that the concentration rose to 60 parts per million at one moment and to 40 at another. The ventilating equipment was therefore modified in order to eliminate these peaks.

Magnetic Inspection of Bolts and Castings



The tubes on the panel control a current impulse of 40,000 amperes for magnetizing bolts and castings. The transformer is mounted on trucks to permit short lead lengths to the test positions

ELECTROMAGNETIC INSPECTION of bolts and other parts made of magnetic material has been made for some time at the Buffalo, N. Y. plant of the Airplane Division of Curtiss-Wright Corp. The equipment used for this purpose shows up flaws and cracks and can handle part sizes ranging from small bolts to reasonably large castings.

When a magnetic substance has electrical current passed through it, a north and a south pole are produced at each crack in the material. When finely divided iron oxide in solution is poured over the material, the oxide particles adhere at the cracks and make them readily visible. The importance of such electromagnetic inspection operations in the production of aircraft has long been considered a vital necessity as a safety measure.

This method of inspection requires a large amount of current and this has been obtained from storage batteries in the past. Main-

wherever a tube is used...

...*for example:* **HIGH-SPEED PHOTOGRAPHY**

The Lee Strobo-Speed lamp stops action of rapid movement with a flash of about one thirty-thousandth of a second. One flash exceeds in light intensity the illumination of 2,000 kilowatts of ordinary tungsten lamps. Operates on 115 volts, 60 cycles, A.C.

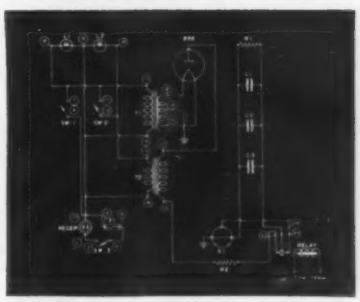
THERE'S A JOB FOR

Relays BY GUARDIAN

In the Lee Strobo-Speed lamp a rectifier tube is employed to build up a high charge on a bank of condensers. These are discharged through the flash lamps when the Guardian Series 15 relay is energized. This special application illustrates the flexibility of design incorporated into Guardian relays. The Guardian standard Series 15 was selected for the job and engineered to meet the high voltage requirements and other special conditions.

Another Lee Strobo-Speed unit with three flash tubes operating from three banks of condensers also employs the Series 15 relay. In this application the relay is equipped with additional switches to handle three circuits instead of one. Contact switches in both units are specially insulated to withstand the high voltages.

The Series 15 is a compact unit having a maximum switch capacity of 10 pole, single throw with 1½ amp. contacts; 6 pole single throw with 8 amp. contacts; 4 pole double throw with 12½ amp. contacts. Coils for standard voltages range up to 220 volts and may be equipped with copper slug time delay on release or attract.



Single Flash Tube, Single Circuit Diagram.

Consult Guardian whenever a tube is used—*however*, Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.

For D. C.—write for Series 15 bulletin. For A. C.—write for Series 30 bulletin.

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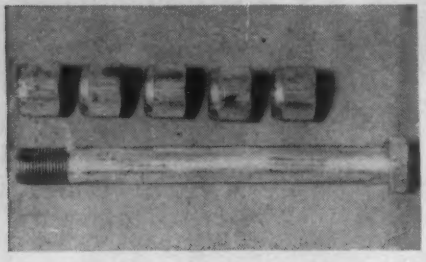
tenance cost on the battery equipment has run approximately $3000 yearly. To cut down this expense, A. E. Soderholm, of the company's engineering staff, started work on a method of using electronic equipment to replace the batteries. As a result of his research and study, electronic units were built to specification by General Electric Co.

The electronic equipment shown in the photograph makes available a source of power which is constant, day in and day out, at a fixed



Cracks and flaws in nuts and bolts made visible by the action of heavy current from vacuum-tube rectifiers through the part under test. Iron oxide collects at the crack

amperage. By the use of thyratrons and ignitrons, a current impulse of 40,000 amperes is available which provides deeper penetration and greater concentration of the oxide-iron particles. The estimated yearly maintenance cost of the electronic equipment is $50, principally for replacement of vacuum tubes.

With the vacuum tube power supply as a source of current, the hazard of fire is completely eliminated as there are no electric arcs. Another advantage is the elimination of lost motion due to periodic shut downs previously experienced during battery changeover and charging periods.

Flame-Failure Control of Industrial Furnaces

IF THE FLAME FAILS in furnaces fired by pulverized coal, oil or gas, electronic flame-failure safeguards can prevent the development of explosion hazards. In its simplest form, the equipment shuts off the fuel supply and attracts the operator's attention by a signal. Such systems may be modified by the addition of various interlocks, furnace purges, automatic ignition, relights, timers, alarms, and other devices.

Operation of the equipment depends upon detecting a flame's existence by a phototube or an electrode, or both. Furnaces burning pulverized coal or oil, in which flame luminosity is light yellow, or brighter, generally use the phototube detector. Ordinarily a blue flame, such as gas burners make, requires an electrode detector which is a conductor of electricity with a resistance of from 1 to 100 megohms.

At flame failure, the resulting change in the current through the phototube or electrode exposed to the flame is amplified by electronic tubes to the desired value. The circuit of one of the simplest forms of flame-failure safeguards is shown in Fig. 1. This system, made by Wheelco Instruments Co., is used on an oil-fired furnace with push-button opening of the fuel valve and manual lighting of the flame with a torch.

Photoelectric System

The diagram shows no-flame conditions, when, for example, the flameguard has been energized but the fuel valve is still closed. The operation of the circuit can be traced by assuming transformer instantaneous polarity as shown. Secondary S_1 supplies current to heat the cathodes of the twin vacuum tube T. Transformer secondaries S_3 and S_5 complete a circuit from cathode C to anode A, secondary S_3, resistor R_1, and secondary S_5. Until there is a flame, phototube P is inactive and there is no potential on

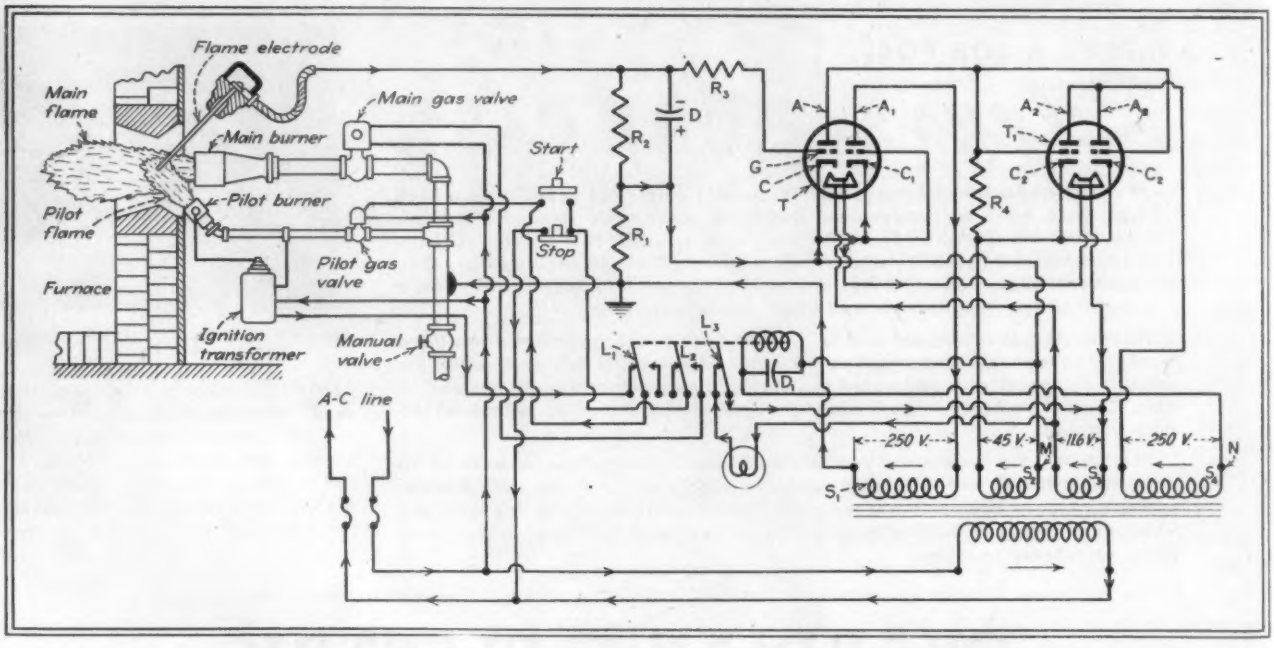


FIG. 2—Circuit of a flame protection system for a gas-fired furnace. Actuated by a flame electrode and electronic amplifier are a solenoid-operated pilot valve, main gas valve, and automatic ignition. The electronic amplifier controls the working units of both the fuel and ignition systems

When that Great Day dawns you'll be in the market for new types of components for your electronic devices now in the planning stage. Among your needs will be resistors embodying those characteristics which the new applications demand.

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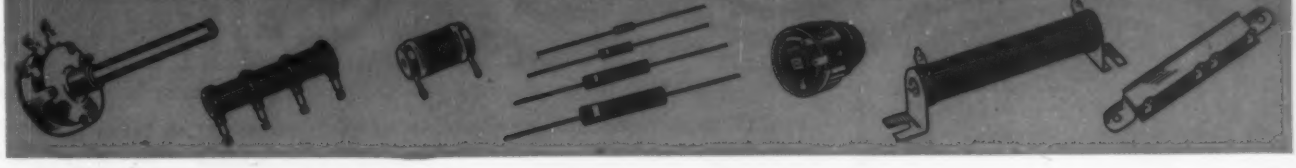

Designed for Application

The No. 10060 Shaft Lock

Another exclusive Millen "Designed for Application" product is the No. 10060 shaft lock. This differs from the self-mounting No. 10061 unit in that it is mounted on a cross arm which can readily be attached to variable condenser frames, brackets, etc., for "behind the panel" applications.

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grid G, consequently current can flow between cathode C and anode A.

The voltage drop across resistor R_1 puts a negative potential on grid G_1. How this potential is produced can be easily seen by considering secondary S_3 alone. If a connection were made between grid G_1 and cathode C_1, current from S_3 would flow from grid G_1 to cathode C_1, then from C to A, and back to S_3.

In the absence of the connection between G_1 and C_1, there exists a negative potential equal to that of secondary S_2, and this side of the tube cannot conduct. As a result the relay coil remains dead, a circuit for this coil being through secondary S_2, cathode C_1, anode A_1, secondary S_4 and back to the relay, but it is blocked by grid G_1.

Relay contacts, therefore, remain closed in the position shown, and the pilot light is energized through contact L_1 to show a no-flame condition.

Valve Open

Closing the pushbutton connects the fuel-valve-opening coil across the line. This valve opens and when the fuel is burning with sufficient flame the phototube conducts on the reverse transformer polarity from that in the diagram. This circuit is from terminal N of secondary S_2, the relay coil, resistor R_3 to ground through the phototube resistors R_3 and R_4, back to S_2. The anode of the phototube connects between R_3 and R_5, which puts a negative potential on grid G equal to the voltage drop across R_3 and R_4, and charges capacitor D.

When the polarity of the transformer reverses, capacitor D discharges through resistors R_3, R_2 and R_4, and maintains the negative potential on grid G to block the circuit between cathode C and anode A. Blocking the circuit removes the potential on G_1, and the right-hand side of the tube completes the relay-coil circuit.

This circuit is from S_3 through cathode C_1, anode A_1, secondary S_4, the relay coil, and back to S_3. Energizing the relay coil causes it to open contact L_1, to extinguish the pilot light and close contact L, to short-circuit the pushbutton and put the fuel-valve coil circuit directly across the line. When the pilot light goes out the operator knows the burner has been lighted and he releases the pushbutton.

Flame Failure

If for any reason the flame fails, the phototube becomes inoperative and removes the negative potential from grid G. Current can again flow from cathode C to anode A to give grid G_1 a negative potential and block the right-hand side of this tube, as previously explained. Since the circuit is blocked between C_1 and A_1, the relay coil deenergizes, to open contact L and close L_1. The former opens the fuel-valve-coil circuit, and this valve closes to shut

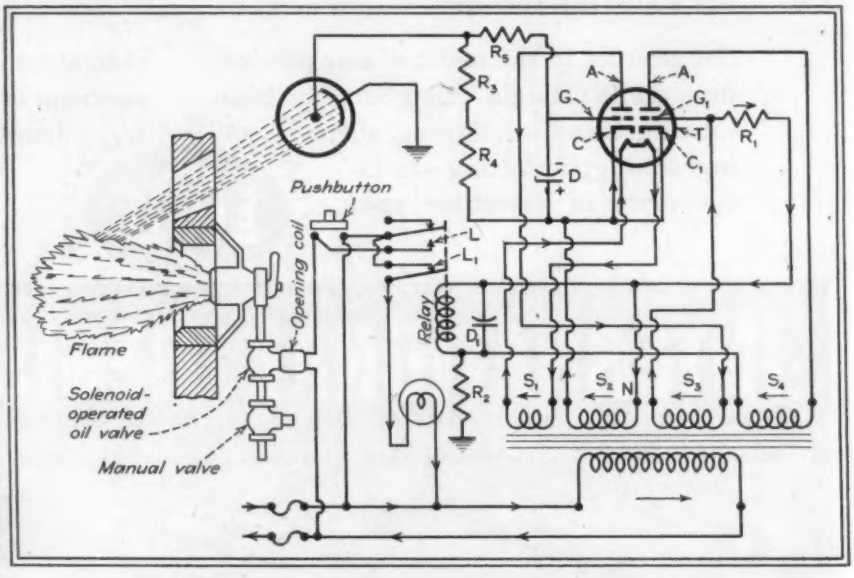

FIG. 1—Simple flame-failure system for an oil-fired furnace. A pushbutton opens a solenoid-operated fuel valve and the flame is lit manually with a torch

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off the oil. Closing of contact L_1 lights the pilot lamp to signal the operator that the fire is out.

To prevent the relay dropping out during transient flame disturbances, such as puffs and flickering, that temporarily shut light off from the phototube, a capacitor D_1 connects across the relay coil. Time delay in relay opening after its coil circuit is blocked depends on the size of the capacitor and the charge on it just before flame interruption. This time can be adjusted but if insufficient to overcome effects of transient flame disturbances, it may be lengthened by increasing capacitance.

Flame Conduction Type

Figure 2, a gas-burning system developed recently by Brown Instrument Co., includes a flame-electrode, main gas burner, pilot burner and automatic ignition. The control part of the system uses two twin vacuum tubes, T and T_1. Assume no-flame conditions with the line switch closed. The cathodes of the two tubes are heated and the pilot light energized from the transformer secondary S_3, as indicated by the arrowheads. Secondary S_1 completes a circuit through resistor R_1, cathode C_1 and anode A_1 of tube T, back to S_1. Under this condition grid G does not have a negative potential and this side of the tube conducts when the polarity of secondary S_2 is the reverse of that shown. This circuit is from terminal M of secondary S_2 to cathode C, anode A, through resistor R_4, back to S_2. Voltage drop across R_4 puts a negative potential on the grids of tube T_1 to block the relay-coil circuit. This circuit, when not blocked, is from terminal N of secondary S_4 through the relay coil, secondary S_2, cathodes C_2, anodes A_2, back to S_4.

Ignition of Pilot

Closing the start button completes the circuit from the line through the ignition coil, contact L_1, start and stop buttons, back to the line, as indicated. A circuit is also completed through the pilot-valve coil, the start and stop buttons, to the line. The pilot valve opens and the ignition system lights the pilot flame and it contacts the electrode. Then a circuit is completed from secondary S_4 through the flame, the flame electrode, re-

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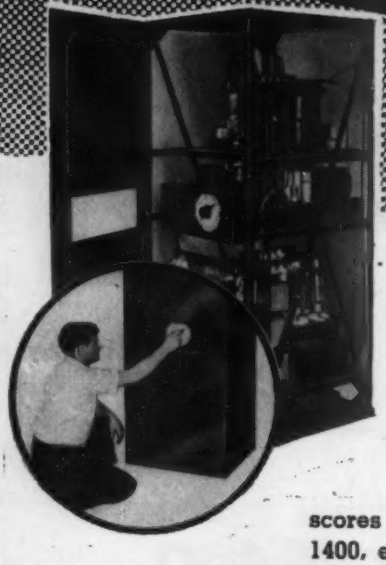

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sistor R_2, cathode C_1 and anode A_1, back to S_1.

Grid G connects, through resistor R_3, between the electrode and resistor R_2 which puts a negative potential on this grid to block the circuit from cathode C to anode A. Capacitor D is also charged and when the polarity of the transformer reverses, the capacitor discharges through resistor R_3 and maintains a negative potential on grid G to block the circuit through R_4 and S_2.

Absence of current through R_4 removes the negative potential from the grids of tube T_1, and the relay coil is energized. The circuit for this coil is through secondary S_2, cathodes C_2, anodes A_2, secondary S_4 and the relay coil. Energizing this coil opens contacts L_1 and L_3 and closes contact L_2. Opening contacts L_1 and L_3 opens the pilot-lamp and ignition-coil circuits, but the pilot valve is held open by the circuit through the pushbutton. When the pilot light goes dark, it denotes that the pilot flame has been established and has contacted the electrode.

Main Flame

Closing contact L_2 completes the main gas-valve coil circuit from the right-hand side of the line, through the main gas-valve coil, contact L_2, the stop button, then to the left-hand side of the line. This valve opens and the operator holds the start button closed, releasing it when the main burner ignites. The main valve circuit remains closed through contact L_2 and the stop button. As long as the flame contacts the electrode, the relay holds its contacts closed to the flame position.

Should the flame fail for any reason, it will remove the negative potential from grid G. This tube will again complete the circuit for secondary S_2 through resistor R_4, to make the grid of T_1 negative and block the relay coil circuit. Its contacts then return to the start position and break the main gas-valve-coil circuit through contact L_2, after which the valve closes. The system then remains in a safe no-flame position until the start button is pressed, when the operations just described repeat.

During normal operation, pressing the stop button opens the main gas-valve coil and this valve closes. The operator holds the button open until

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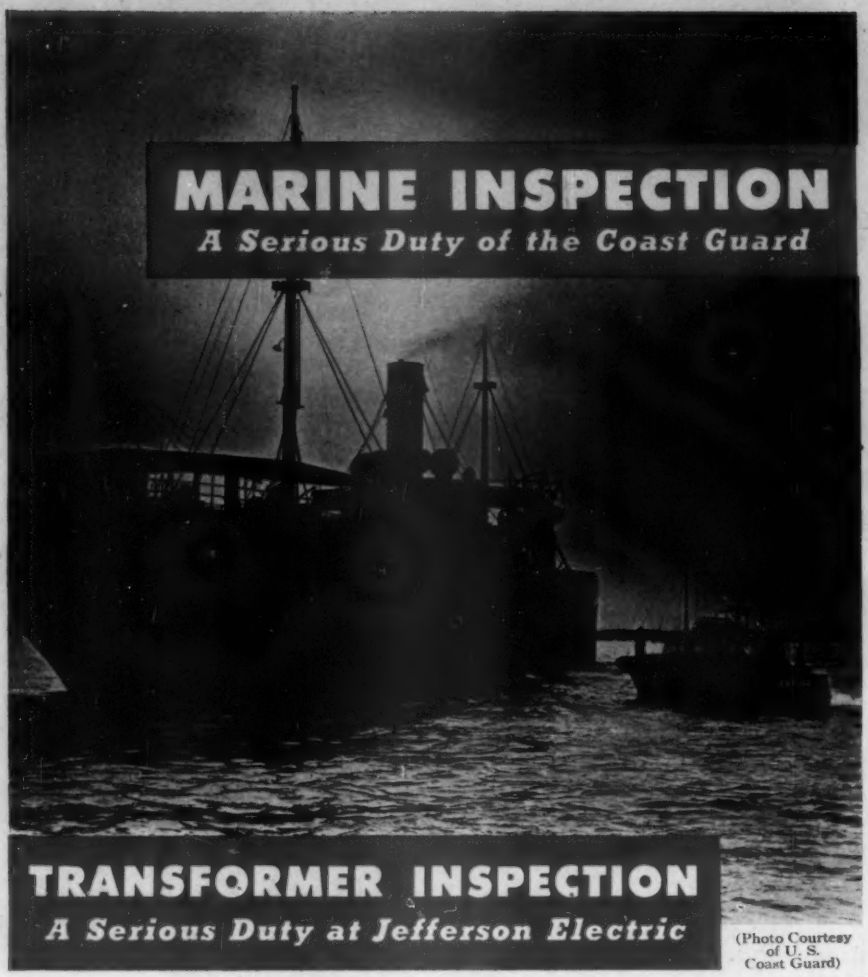

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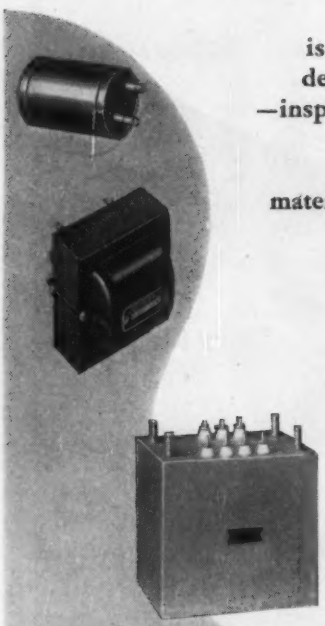

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he sees the pilot lamp light, when he knows that the equipment has returned to safe no-flame position.

If the electrode were to bend down and touch the gas burner it would form a closed circuit to ground the same as when a flame exists. This danger is provided against because when the electrode grounds, capacitor *D* discharges so rapidly that the potential on grid *G* decreases to where its side of the tube conducts and makes tube *T*, grids negative to block this tube. The tube then acts the same as when the flame extinguishes; the relay opens its contact to close the fuel valve and light the pilot light. This system is therefore protected against either breaking or short-circuiting of the electrode. If the electrode breaks and does not contact the flame, it creates no-flame conditions to close the main fuel valve automatically. Grounding the electrode also closes the fuel valve.

• • •

Industrial Applications of the Fluoroscope

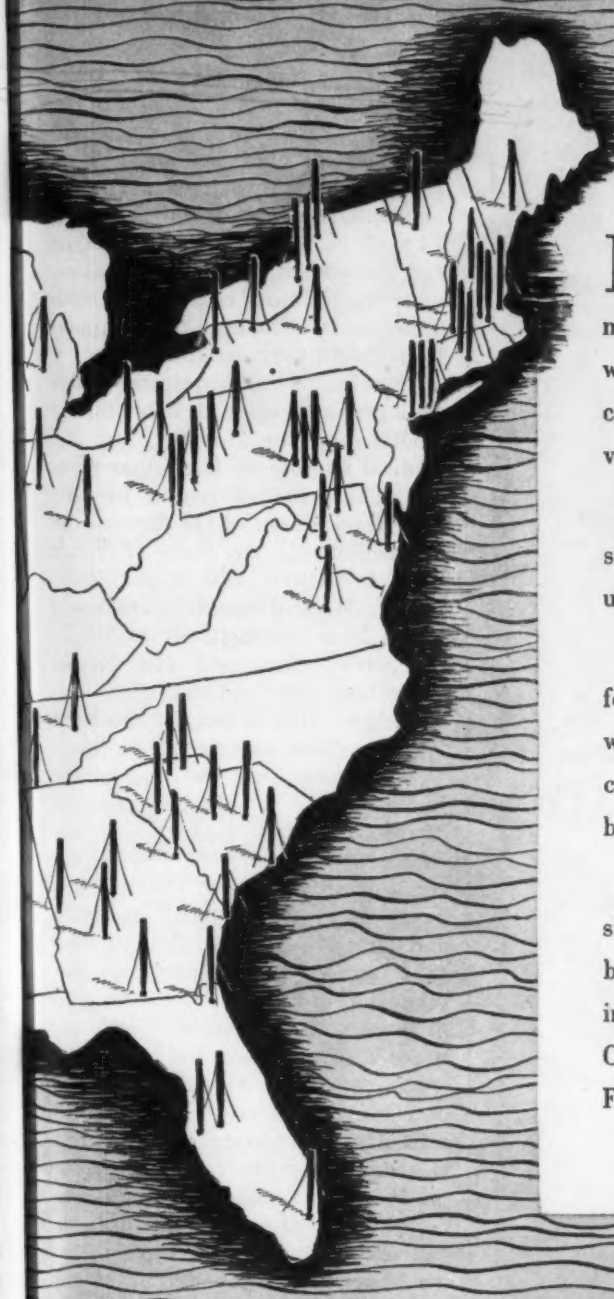
A COMPARISON of radiographic and fluoroscopic techniques that have been developed as part of the expansion of industrial x-ray use since the start of the war was made by R. W. Mayer of Kelly-Koett Mfg. Co. in addressing the Pittsburgh section of the American Industrial Radium and X-ray Society. He pointed out that the Government, as a customer, will not be in the picture to require x-ray inspection of airplane castings, tank welds, armor plate, etc., from the sole standpoint of safety—although there might be some government safety regulations calling for x-ray inspection of certain vital parts of airplanes used as public carriers.

"Many industrial x-ray users who started using the equipment originally because of government requirements, have learned the value of inspection beneath the surface for the information it provides, enabling them to improve quality, reduce costs and save labor. It is likely that these users will pass along what they have learned and establish acceptance standards of their own on purchases of castings, welded parts and assembled units.

Equipment

"One contribution to industrial x-ray expansion is the improvement

ON THIS MAP?



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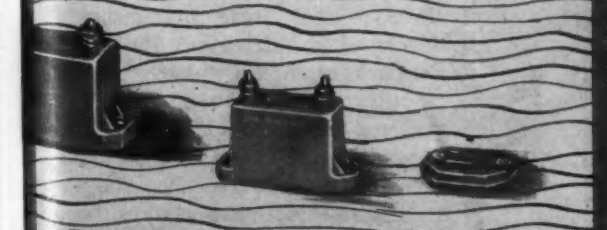

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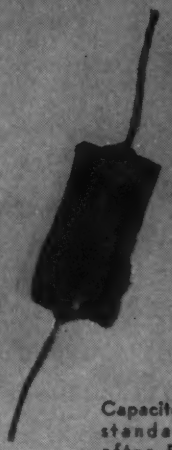

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of presently available types of x-ray machines and the creation of new machines and accessory devices as our own knowledge increases. Progress thus far has been much greater along the lines of straight radiography than on fluoroscopy. The reason for this is that x-ray has been, for years, a tool for the medical profession and equipment and medical traditions have been carried over into industry. For example, the standard medical size 14 x 17 in. film is just about right for the human torso, but no engineer would have established such dimensions, although they happen to work out very satisfactorily.

"Medical x-ray equipment for radiography required only minor modification for industry, but the medical fluoroscope is another matter. The principal reason for the slow development of the fluoroscope in medicine is the limit of x-ray that a patient can stand with safety. Medical machines are made to cut back automatically to 5 milliamperes when used for fluoroscopy, and the radiologist is extremely careful to restrict the time that a patient is exposed.

"For some time the fluoroscope has been used to spot the presence of foreign bodies in packaged food, tobacco, soap, cereals, etc. One large manufacturer of chewing tobacco experienced labor troubles and when the strikers left their jobs they tossed nails, hairpins, and other foreign articles into the pile of unpackaged tobacco. That tobacco company now has a fluoroscope, and a girl observes and checks every package. There is no difficulty in detecting such impurities since they are usually metallic or, at least, of a density vastly different from the pure article, and fall under the general heading of gross defects. The only problems on such inspection are those of a mechanical nature.

Improved Sensitivity

"Fluoroscopic inspection permits instant separation of the good from the bad—no waiting for films to be developed and dried, no film at all, no dark room, no delay. Savings mount, costs go down, and for these reasons there have been many attempts to widen the field of application of the fluoroscope, but the stumbling block has always been

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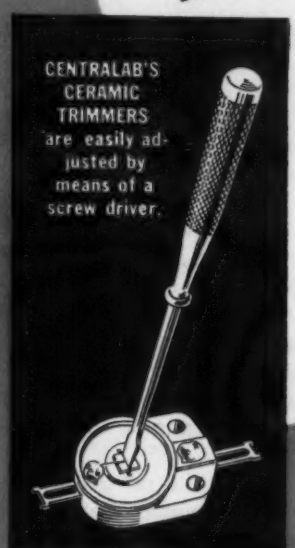

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lack of sensitivity. Until very recently, a sensitivity of 15 percent was considered normal, 10 percent good, and under very unusual circumstances, 8 percent might be seen. Today, these limits can be just about cut in half and a sensitivity of 5 percent or better can be counted on as a regular day in and day out production standard.

Limitations

"It is well to recognize some of the inherent limitations of fluoroscopy. In the first place, radiographic technique charts on penetration do not apply. Considerably higher voltages are required on a fluoroscope than on a film. The time factor, which permits the effect of the x-rays to accumulate on film, is totally absent on the fluoroscopic screen. The screen shows only the instantaneous image. True, there is some "after glow", but that is a different phenomenon entirely.

This limitation immediately translates itself into a limit of thickness that can be fluoroscoped because it is not practical to use a unit of more than 220 kv or 250 kv capacity for fluoroscopy. The reason for this limit is principally a matter of safety. As the voltage is increased over these limits, there must be more than a proportionate increase in the thickness of lead and lead glass of the viewing cabinet. Moreover, with fluoroscopy, the x-ray is left turned on for a much longer period of time than is the case with radiography, which increases the importance of providing adequate protection. Our industrial laboratory has found the practical limits to be approximately 2" of aluminum and approximately ½" of steel.

"A second limitation is sensitivity. Radiographic penetrameters are based on 2 percent sensitivity, although on good radiographic work, flaws on the order of 1 percent can be shown. While some excellent sensitivity claims have been made on the part of reliable observers, we prefer to state that the fluoroscope is practical for sensitivities of 5 percent and a little better, at this time.

"Thirdly, the fluoroscopic screen provides no permanent record. The results obtained are in what the observer sees and if a check is re-

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Recently, a manufacturer building secret military apparatus called for a small, compact electric motor that provided unfailing, uniform slow speed. Since standard "off the shelf" gear motors could not meet the strict performance and design specification, the only solution was a special motor.

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Today, Holtzer-Cabot is designing and building special fractional HP motors for war products, only. However, our motor development engineers, backed by over 50 years of experience in electric motor design will gladly cooperate with you on your motor requirements and problems for post-war products.

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July 20th a Star was added

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quired, other means must be used.

"Fourthly, the degree of success with fluoroscopy depends on personal factors to a greater degree than is the case with radiography.

Advantages

"These limitations have been listed in order to make it clear that fluoroscopy must not be considered a complete substitution for radiography. In the final analysis, the fluoroscope has definite advantages of time and cost and also has certain exclusive advantages of its own. For example, a radiograph provides a picture in only one plane, but in a fluoroscope the part can be rotated which provides a third dimension to definitely fix the location of the defects. Also, certain types of defects, such as cracks and fissures will only appear on a film if the part is so placed that the plane of the crack lines up with the direction of the x-ray beam. The chances are very slim indeed of being able to place a part on film in exactly such a position, but in a fluoroscope the part can be twisted and turned until—suddenly—there it is.

"On most applications, fluoroscopy will find its greatest value as a supplement to radiography rather than to be used alone. That is, the ultimate in an inspection set up—that lends itself to fluoroscopy at all—is a combination layout arranged to provide ready changeover from one to the other without sacrificing any of the advantages of either.

Needs

"Let us consider what this involves. A fluoroscopic screen is observed through lead glass and the only practical arrangement involves the use of some sort of lead lined cabinet with lead glass viewing window. Since such a cabinet must have all the elements of protection required for radiography, and since the same x-ray generating equipment can be used for both fluoroscopy and radiography, it becomes unnecessary to construct a separate lead lined radiographic room provided, first, that cabinet be designed to be adaptable for either radiography or fluoroscopy; and, second, that the control do double service.

"For the control unit two things

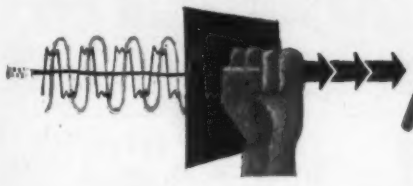
A WIDE RANGE OF TUBES — OF WIDE APPLICATION

THE enviable engineering tradition on which the foundation of the North American Philips Company, Inc., rests, is reflected in the superior quality and performance of electronic tubes bearing the NORELCO stamp. Contributing to the long life and uniform characteristics of these tubes are many exclusive manufacturing techniques and inspection methods developed over a long period.

Among the types we now manufacture — some of which are illustrated — are a number of special-purpose, cathode-ray and transmitting tubes for high and ultra-high frequency applications, r-f and a-f power amplifier tubes, and low- and high-power rectifiers. Although all the tubes we produce now go to the armed forces, we invite inquiries from prospective users. A list of the tube types we are especially equipped to produce will be sent on request.

In the North American Philips Company, there is gathered together a team of outstanding electronic engineers, captained by one of America's leading physicists, and coached by a group with world-wide experience resulting from fifty years of research and development in the electrical field. This new combination of technical talent has at its command many exclusive processes that insure electronic devices of the highest precision and quality. Today, North American Philips works for a United Nations Victory; tomorrow, its aim will be to serve industry.

NORELCO PRODUCTS: In addition to the electronic tubes mentioned above we make Quartz Oscillator Plates; Searchray (X-ray) Apparatus, X-ray Diffraction Apparatus; Medical X-ray Equipment, Tubes and Accessories; Electronic Measuring Instruments; Direct Reading Frequency Meters; High Frequency Heating Equipment; Tungsten and Molybdenum products; Fine Wire; Diamond Dies.



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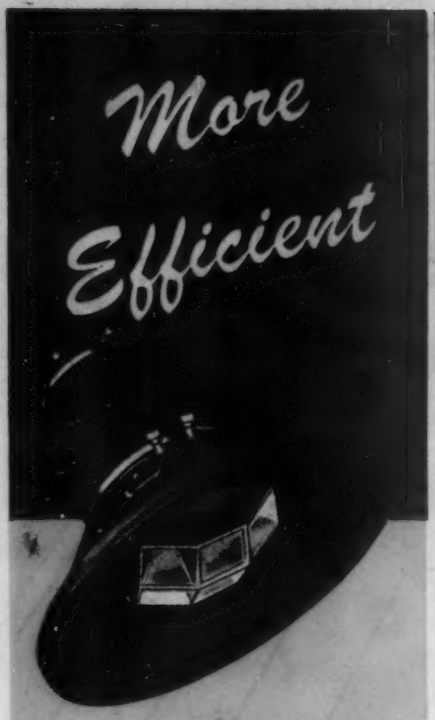

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are involved. The first is a foot switch control for the fluoroscopic observer, a very simple addition to any x-ray control unit; and the second is to provide stepless control of kilovoltage to permit adjustment, to whatever value is required to penetrate the particular section under observation. Regarding the cabinet, the actual development has been from the radiographic side. For some time, it has been recognized that a cabinet has certain advantages in cost, convenience and flexibility over the construction of a lead lined room."

• • •

Ultraviolet Radiation Reduces Absenteeism

USE OF ULTRAVIOLET RAYS in business offices to curb epidemics of respiratory diseases responsible for so much absenteeism is demonstrated by the experience of a company in Boston, Mass. The firm employs 70 men and women and protects them from germs with a constant daily radiation barrage from 15 carefully placed irradiators. Graph chart records kept from December 1 to March 1 reveal an average reduction of absenteeism due to illness of over 25 percent, while the decrease effected during the height of the influenza epidemic amounted to 66 percent.

In Boston, Dr. Richard Overholt has carried on extensive research in irradiation, particularly in relation to hospital operating rooms and the prevention of post-operative infection. His own offices have been equipped with air sanitation by engineers of Hanovia Chemical and Manufacturing Co., Dr. Overholt was successful in reducing the overall infection rate by more than 30 percent.

Schirmer-Atherton Co. decided to try out a similar plan to prevent cross-infection in a business office. Twelve ultraviolet irradiators were installed 20 feet apart to protect a total space of approximately 60,000 cubic feet. Three other installations take care of an additional 20,000 cubic feet in separated offices. All irradiators are placed at an approximate height of eight feet from the floor and the rays are thrown upward to protect occupants' eyes from skin or eye redness.

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Displaying excellent stability under adverse climatic and operating conditions, an additional feature of IN-RES-CO wirewound resistors is their low distributed capacity. The new IN-RES-CO catalog covering the complete line of dependable resistors, meter shunts and multipliers is available. A note on your company letterhead will bring it promptly.

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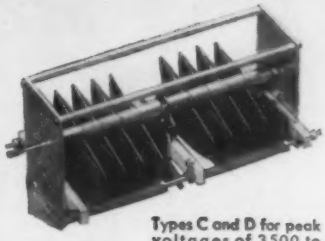
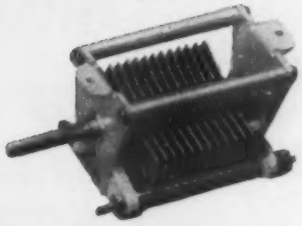


Types C and D for peak voltages of 3500 to 13,000



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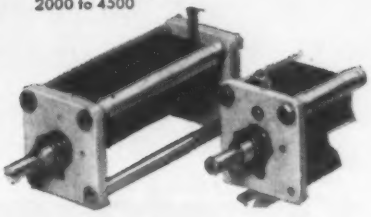

Type H for peak voltages of 1500 to 3000

Type N neutralizing condensers in 5 sizes

Again Johnson scores a first with newly designed thick plates which allow much higher voltages, particularly at high frequencies.

It has long been known that plates with rounded edges have higher breakdown voltages in variable condensers, but it remained for Johnson Engineers to work out ratios of plate thickness, design, voltage, and spacing for maximum advantage.

Greatly decreased length (as much as one-third in some cases) results in lower minimum capacity and lower inductance due to shorter frame rods and other metal parts, which is extremely important at high frequencies.

Corona is noticeably less with the new type plates and corona shields have been added where stator bars enter insulators, resulting in still further improved performance.

Despite these many improvements, in most cases prices are lower because of the saving in material.

Now available in Types A and B, both fixed and variable, this new plate shape and construction will be incorporated in other types as quickly as possible. Write Johnson today for more information and for recommendations on YOUR variable condenser application.

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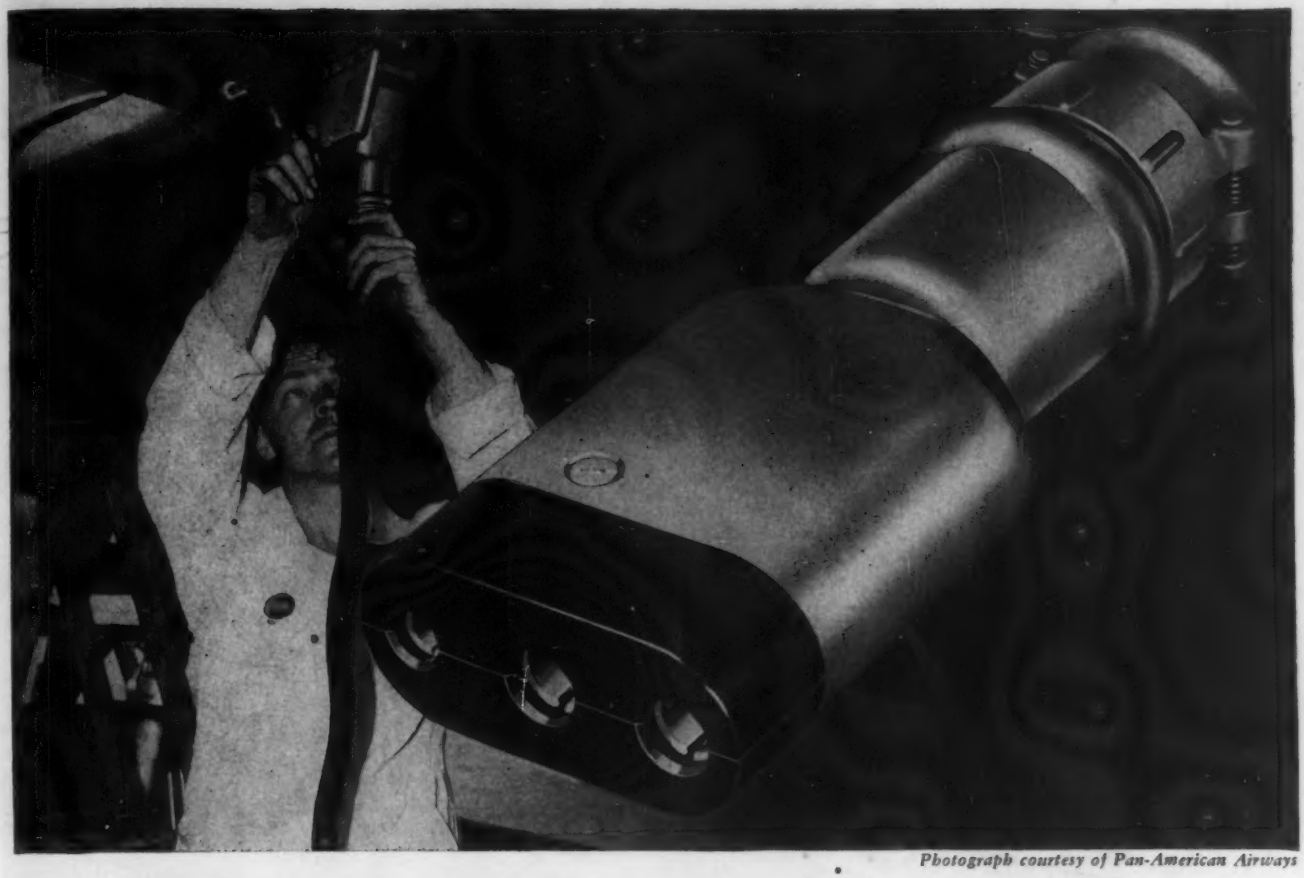


Photograph courtesy of Pan-American Airways

THE RUBBER SHORTAGE INSPIRED THIS AIRPLANE BOOSTER PLUG

Another Engineering Accomplishment of The Hubbell Development Laboratory

WHEN the rubber situation became acute, an all-rubber plug was being used to supply a booster charge for starting aircraft motors. As a conservation measure, the aircraft industry asked the Hubbell Development Laboratory to re-design the plug using less critical material.

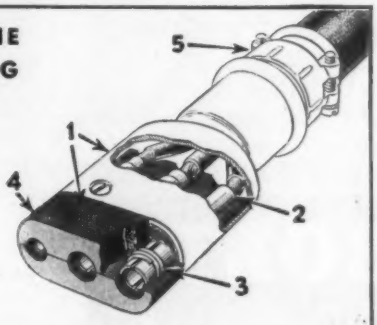
Working with plastic and metal, Hubbell engineers produced the external power plug shown here. Its principal advantages are described below. So completely satisfactory is this new plug that it has received wide acceptance and will unquestionably continue to be used after the war.

Hubbell Development Laboratory is an engineering organization serving all of industry. Its purpose is to produce electrical sockets, receptacles, switches and connectors to meet specific requirements. Most of these devices in general use today are either Hubbell-designed or Hubbell-improved. If you have some problem involving products of this nature, write to the Hubbell Development Laboratory. Whether the solution is a simple alteration of some standard unit or the creation of an entirely new design, you can count on complete satisfaction. One of our technical advisers will be glad to call on you to discuss your requirements. This involves no obligation.

APPLICATION SUGGESTIONS WELCOMED. If you believe that the modification of any electrical outlet receptacle, switch, or connecting device will give the product broader application, send your suggestions to the Hubbell Laboratory. Also, if you have any Hubbell products, the uses of which you think are unusual, we would like to know about them. Your ideas may help others solve a problem.

5 ADVANTAGES OF THE HUBBELL POWER PLUG

1. Heavy armor and impact resisting plastic make this plug practically indestructible.
2. Can be re-wired in case of power cable damage.
3. Non-current carrying reinforcing springs assure contact pressure indefinitely.
4. Insulation extends beyond armor eliminating danger of short circuiting.
5. Designed for use with standard AN cable clamps.



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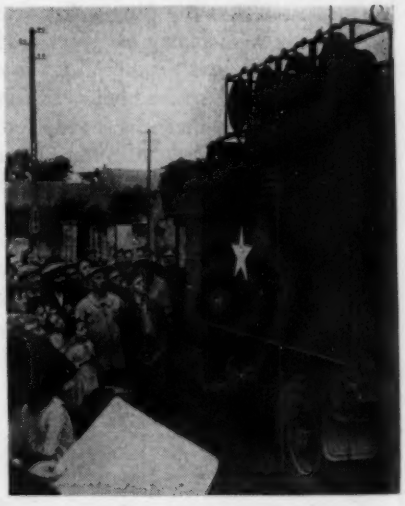

French villagers, whose radios were confiscated by Germans, listen to BBC news broadcasts from London by means of a traveling radio truck with multiple horn speakers supplied by the Psychological branch of the British Army

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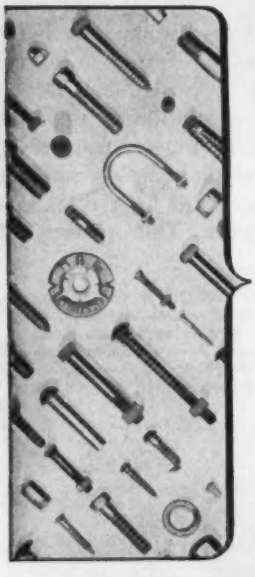

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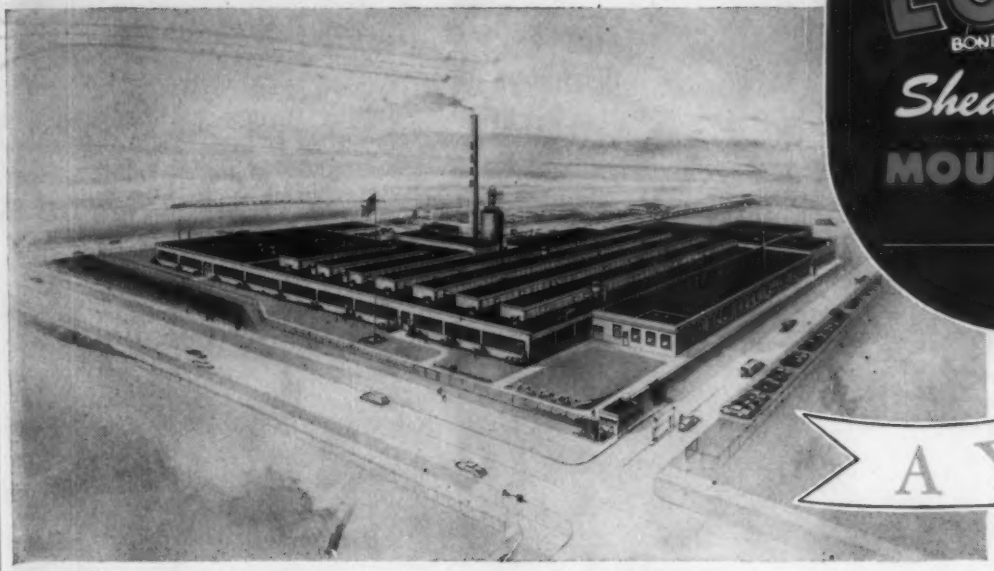

"LORD MOUNTS", as they are generally known, are being produced at the rate of many millions per year. A large proportion of this production is of *synthetic rubber*, which has proved in the main, to be as effective as natural rubber in flexible mounts for Vibration Control.

The entire facilities of the Lord factory are used to produce mountings and other bonded rubber products, and the energies of the research, development, and field engineering staffs, are devoted exclusively to the improvement of these products for industrial and military use. By specializing, Lord is producing mountings that are the criterion in the flexible suspension field.

The method of bonding rubber to metal, which Lord has developed, permits the use of the rubber in such manner that the stress is always in shear, thus providing the proper deflection for a given load. The final result is a mounting system which provides the greatest efficiency in vibration isolation.

Lord Mountings are small, compact, lightweight units, easy to install and load ratings range in small increments from a few ounces to several thousand pounds. They prolong equipment life, lower maintenance costs, insure greater accuracy of operation, reduce material weights by eliminating the necessity for inertia masses, increase personnel efficiency by eliminating nerve-wearing noise and vibration transmitted through solid conduction.

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TUBES AT WORK

Electronic Tester for Electric Cords and Cables 186

Multi-Channel Radio Link 186

Tropical Failures of Electronic Components 198

Electronic Indicator for Detonation 222

Secret Military Tube has Elements in Parallel Plane 234

Electronic Tester for Electric Cords and Cables

AN ELECTRONIC cable tester, designed and constructed by Consolidated Vultee Aircraft Corp., takes the guesswork out of checking the breaks in electric extension cords and those used on small power-driven tools.

The circuit of the unit is shown in the diagram. One electronic tube is connected as a self-excited oscillator operating on a frequency of about 400 cycles. The output of the oscillator is applied to the cord.

A small amount of the signal energy is picked off the cord by a metal ring through which the cord is passed. Fed to a high-gain amplifier, the signal amplitude is increased sufficiently to operate the output meter shown. When a break in the conductor passes through the ring, a sudden change in the meter deflection occurs and the broken spot can be quickly and accurately ascertained. Thus, the necessity of cutting the cord in more than one place to locate the braek is eliminated.

The metal pickup ring is mounted inside an assembly of fiber insulation material that surrounds the cable during use of the instrument. A short shielded lead is provided for connecting the ring to the amplifier. The ring is mounted on top of the test unit.

Input and output potentiometers are provided to permit adjustment of the circuit so that the meter reading occurs at a convenient portion of the scale when a good cable of the type to be tested is inserted in the ring. Additional provision for this purpose is the use of different values of resistance in the output circuit. Besides the output terminals shown in the diagram, made and female receptacles for the cable plugs used in the Vultee plant are contained in the tester.

Multi-Channel Radio Link

By A. C. PETERSON, JR.

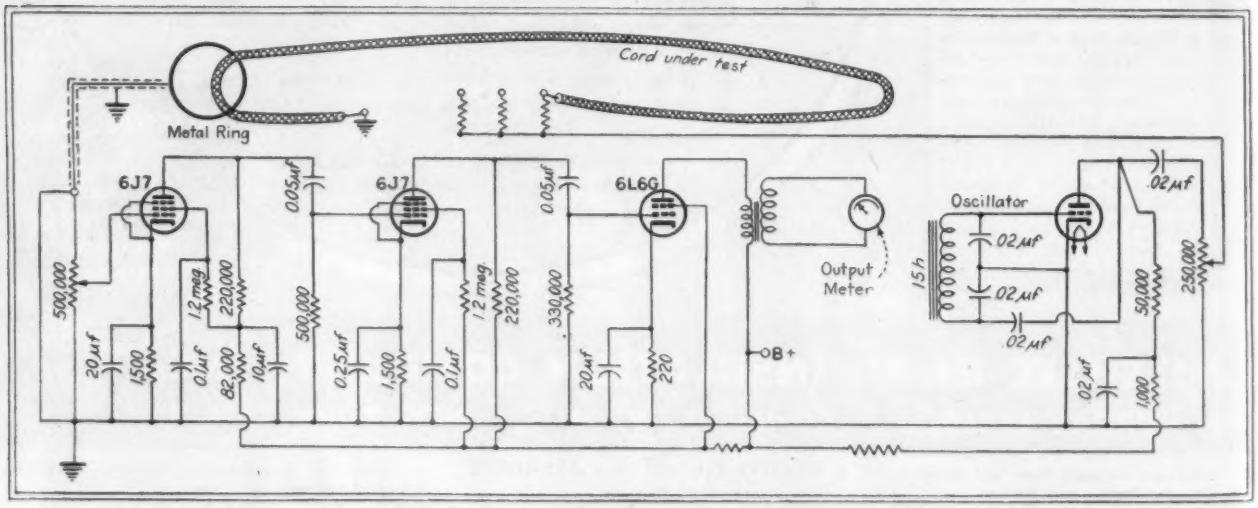
Radio Transmission Engineering
Bell Telephone Laboratories

RADIO LINKS as extensions of land telephone lines are not new. There is one between Boston and Cape Cod that has been in service for a number of years, and there is the more recent installation between Crisfield and two of the islands in Chesapeake Bay. These installations use single-channel links; their radio circuits carry only single conversations.

Over a new radio link between Norfolk and Cape Charles, in southeastern Virginia, as many as twelve conversations may be transmitted simultaneously. Whereas the earlier radio links transmitted the frequencies from 200 to 3000 cycles comprising a single voice channel, the new link transmits twelve voice channels which have been modulated to form a group from 12,000 to 60,000 cycles.

Telephone communication from Norfolk and other points south and west of Chesapeake Bay has had to pass through Washington and Baltimore over some 400 miles of land line to reach Cape Charles. This situation has now been changed by the installation of the radio link. Not only is the circuit reduced to less than a tenth of its former length, but the traffic over the Baltimore and Washington routes is lightened.

The group of twelve channels



Cords and cables are tested for breaks by the amplifier and oscillator connected in the circuit shown above. The cord under test and the metal ring act as the coupling medium between the two units

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employed is that used by the type-K carrier system (carrier system developed by Bell Labs in which lower sidebands of 12 carriers are transmitted over cable) now being installed on cables all over the country. Twelve voice frequency circuits arriving at Cape Charles, for example, are passed through a type-K carrier terminal. The resulting frequency band, extending to 60 kc, is then modulated in the radio transmitter and is sent through the ether to Cape Henry on a wavelength of about six feet.

After demodulation in the radio receiver, the 12- to 60-kc band is transmitted over a cable to the Norfolk office. Here it is passed through a type-K receiving terminal, and the twelve channels resulting are brought to the Norfolk toll switchboard as twelve separate voice channels. The arrangement is indicated schematically in an accompanying illustration. The radio system operates continuously and unattended.

Antennas

Steel towers nearly two hundred feet high support the antennas at each terminal. Each transmitting and receiving antenna consists of two parallel arrays of half-wave elements, one behind the other. The front array contains twenty-four horizontal radiating or receiving elements, while the rear array contains twenty-four similar elements that act as parasitic reflectors.

A view of the Cape Charles

Two parallel arrays of half-wave elements mounted 200 feet high form each antenna in the radiotelephone link across Chesapeake Bay

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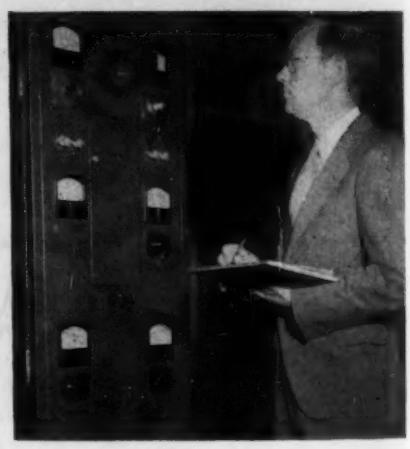
tower and antennas is shown. The transmitting antenna is at the top of the tower, and the receiving antenna directly beneath it. Coaxial transmission lines connect the antennas to the radio equipment in buildings near the base of the towers.

The radio equipment is operated from commercial power lines but at each terminal a stand-by generator, driven by a gasoline engine, has been provided to insure adequate power in emergencies. These auxiliary generators start automatically on failure of the commercial supply.

Type-K Carrier

Although the radio link forms what is essentially a short type-K carrier line circuit, it differs from it in several respects. With the type-K carrier system, the group of twelve single sidebands resulting from the modulation of twelve speech bands is transmitted over the cable as a single sideband of the group carrier frequency.



Meter readings of the radio transmitter at Cape Charles are taken by D. M. Black

The radio transmitter, on the other hand, transmits a double sideband of the type-K carrier group, and thus requires a total band width of 120 kc, instead of the 60 kc transmitted over the cable. A double sideband transmitter was decided upon since it is simpler and less expensive to build.

Another difference is in the regulating scheme. The radio receiver employs automatic gain control to compensate for variations in loss over the radio path. Additional overall regulation is provided for the complete system

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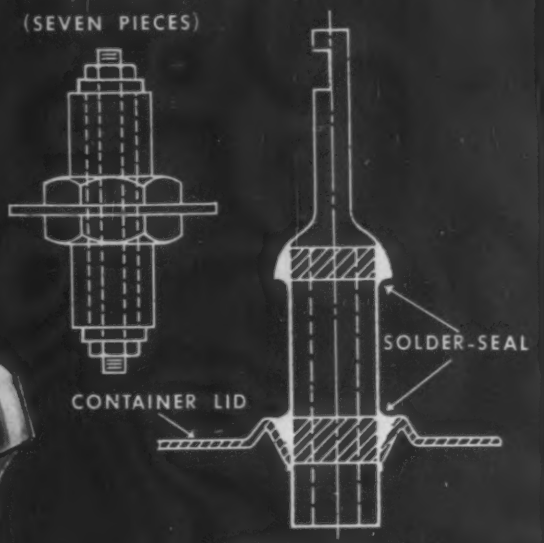

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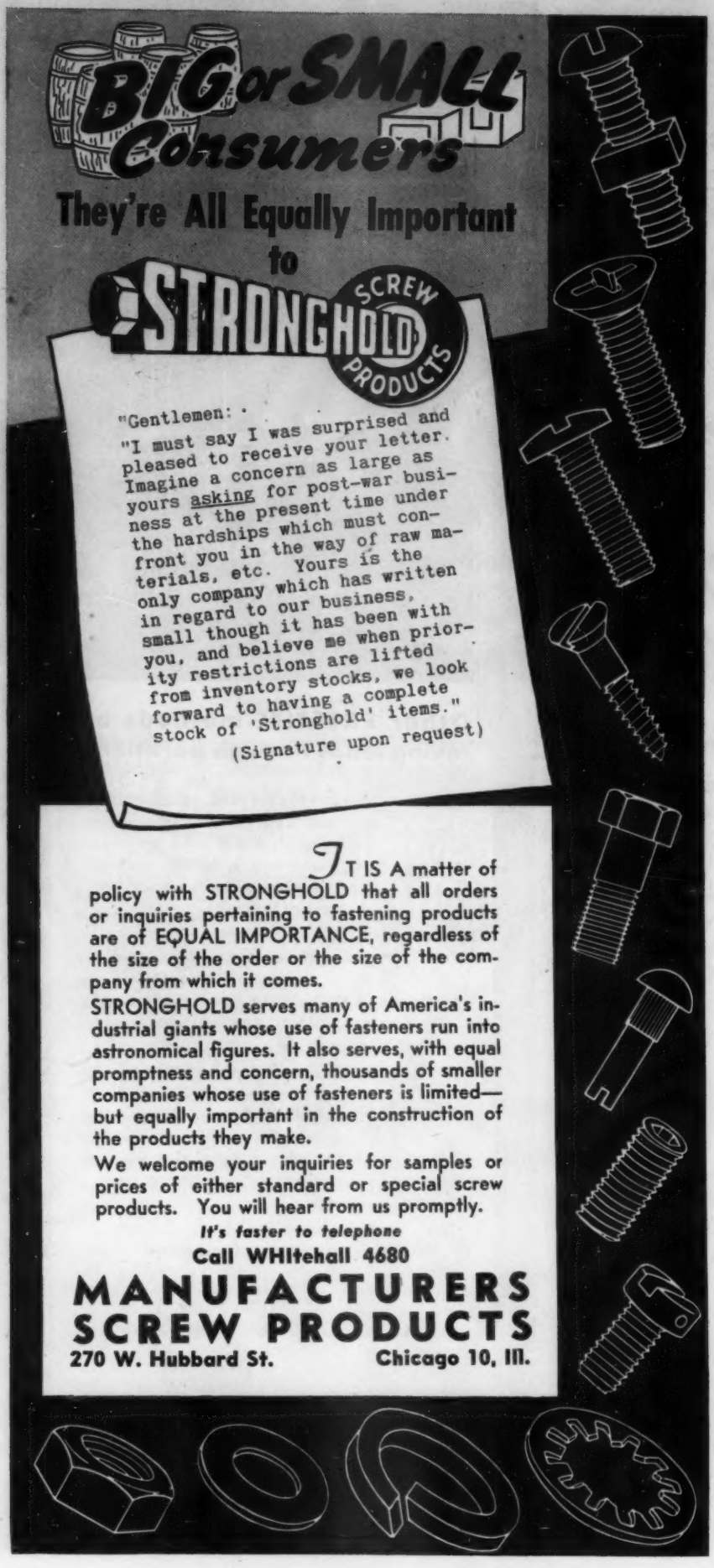
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between Norfolk and Cape Charles to maintain a substantially constant net loss between terminals. This follows type-K carrier practice, in that the gains of the receiving amplifiers are controlled by means of pilot frequencies transmitted in the frequency space between speech bands. As a result, the net loss of each of the twelve channels is held constant to within ± 0.5 db.

To check the frequency of the carrier of the distant transmitter, each radio receiver has an alarm circuit fed through a crystal filter. A deviation in carrier frequency of as little as 0.002 percent will operate this alarm. Alarms are provided to warn of excessive temperatures, power failure, and other conditions that might ultimately affect the satisfactory operation of the system.

The voice-frequency bay of the Cape Charles terminal in the multi-channel radio link is checked by J. O. Smethurst

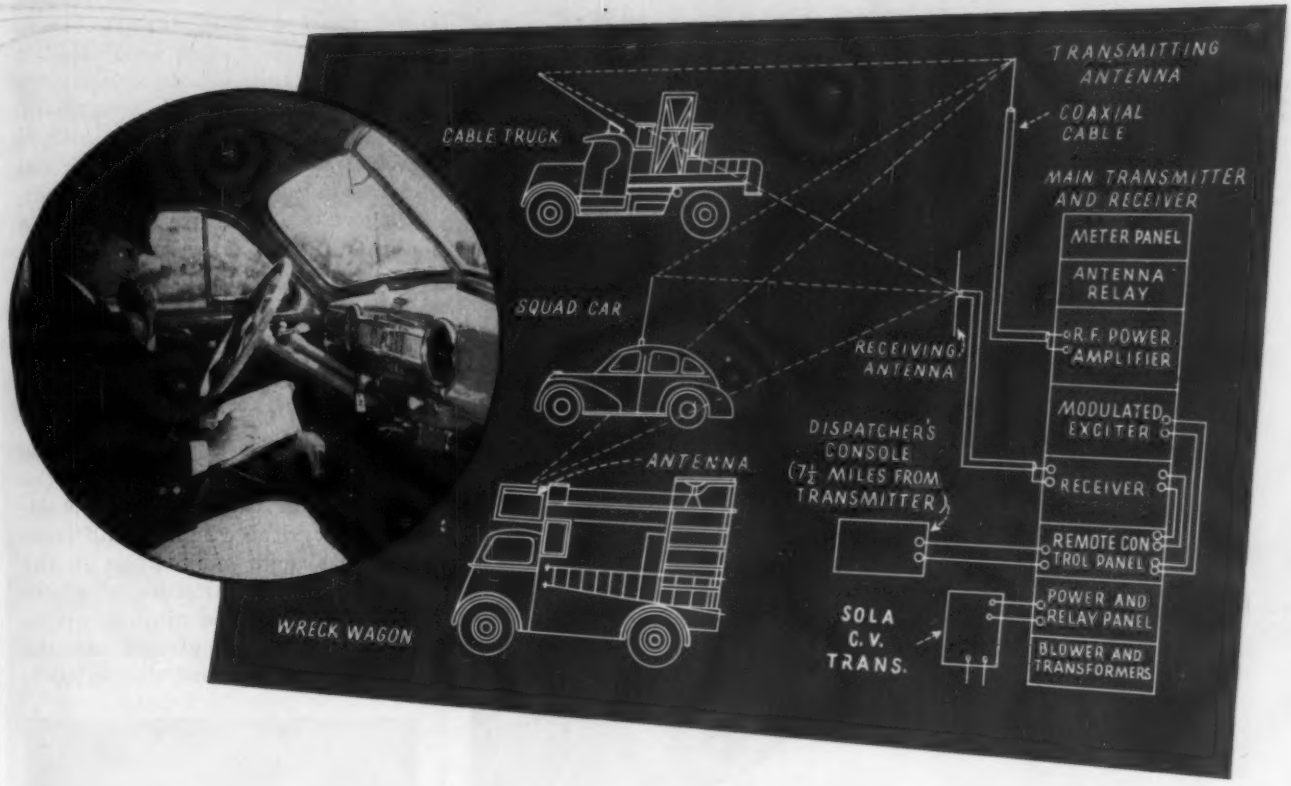
Each receiver is also equipped with an oscillator of such a frequency as to permit the output of the local transmitter to be detected. This permits a "loop" test to be made through the local transmitter and receiver. Whenever the transmission alarm indicates a circuit failure, these loop tests are made at each end of the radio circuit to determine the location of the trouble.

• • •

Tropical Failures of Electronic Components

THROUGHOUT THE GEOGRAPHICAL belt called the wet tropics, electronic equipment gets its toughest test, not only in service, but even before it is unpacked for use. In this non-temperate climate, temp-

RADIO COMMUNICATIONS operate with greater efficiency with built-in CONSTANT VOLTAGE



The safety and convenience of two and a half million passengers, carried daily by the Chicago Surface Lines, are guarded continuously by the elaborate, phase-modulated radio communication system by which all divisions of this vast transportation system are kept under constant surveillance.

Naturally, any communication system so important to human safety and well-being cannot take chances with its equipment. Line surges, voltage fluctuations that distort and interrupt signals or damage costly tubes and equipment, cannot be tolerated.

In this, and in many other radio communication systems, SOLA Constant Voltage Transformers are playing an important role—constantly on guard against line voltage disturbances, instantly correcting fluctuations as great as 30% to less than ±1% of rated requirements. SOLA Constant Voltage Transformers require no manual adjustments or supervision. They have no moving parts. They protect both themselves and their loads against short circuit.

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erature has a year-round average of about 80 deg. F, while humidity stays about 85–90 percent.

Moisture, resulting from this extreme humidity, corrodes metal parts directly and facilitates fungus growth which causes related damage and service failures. Once moisture penetrates insulation it causes leakage, shorts, electrolytic action, and eventual breakdown. Difficulties with electronic components take a number of typical forms in the cases of various specific parts. These are discussed in the following text, with notes on design factors that have been obtained from a branch of the armed forces concerned with such troubles.

Transformers

• Breaks caused by electrolytic corrosion frequently occur in the windings of transformers. Moisture enters the windings and insulation through small holes in the impregnation, particularly where the leads enter the windings. Fibrous or paper insulation absorbs and retains moisture, and in addition, contains water-soluble salts which, when combined with moisture, cause leakage and corrosion. Electrolytic action takes place, and the result is an open circuit. Failures of this sort are frequently preceded by intermittent noises.

Amid typical tropical surroundings, communications equipment is set up in Dutch New Guinea by American troops that landed at Hollandia

To prevent such failures, insulating materials should be used which do not absorb moisture, and the windings must be thoroughly dry and sealed from the damp atmosphere. Among satisfactory coil assemblies are those which have been impregnated with synthetic ceresin and sealed in their cases by potting.

Most common failures from electrolysis result when fine wire is used in the coils. Whenever potential differences exist between windings and cases, it is sometimes feasible to prevent electrolysis by insulating the case and providing a leakage path between the highest voltage and the case. However, certain hazards may be introduced because additional high-voltage areas will be exposed. Electrolysis occurs only when differences of potential exist.

Capacitors

• Unless they are properly impregnated, capacitors which are not hermetically sealed are not suitable for tropic use. Most capacitors, when new, have high leakage resistance, generally in excess of 1000 megohms. But unless they have been properly treated, this resistance, after a few weeks exposure to tropical moisture, may decrease to a few megohms. A resistance of five megohms or less is usually unsatisfactory in high-voltage decoupling capacitors and particularly in coupling units used between plate and grid circuits. Grid bias is made more positive than the proper value by the influence of the plate voltage.

Molded mica-type capacitors have a direct opening where the leads pass through the case; this leaves a path to the outside atmosphere. In the wet tropics, moisture will enter and follow this path and eventually cause failure of the unit.

This trouble can be largely prevented by impregnation with ceresin wax. If properly done, this will seal molded capacitors, provided the leads are not bent or disturbed so as to cause the seal around them to fail. Since ceresin has a relatively low melting point, the wax will become fluid at high operating temperatures. However, this will not prove serious in the operation of the capacitor since the wax will remain in the pores by capillary action and, upon cooling, will actually improve the seal rather than impair it. However,

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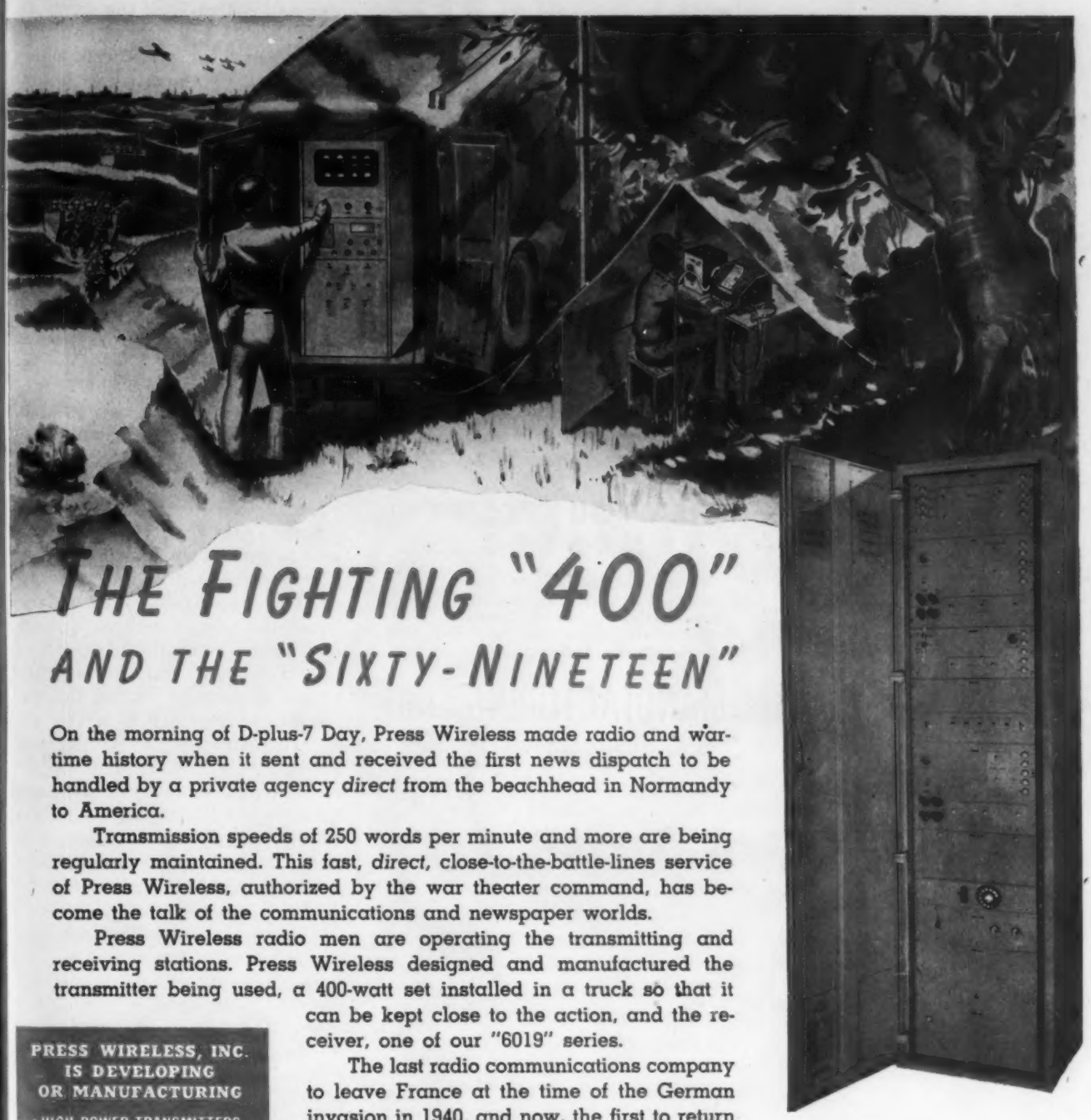

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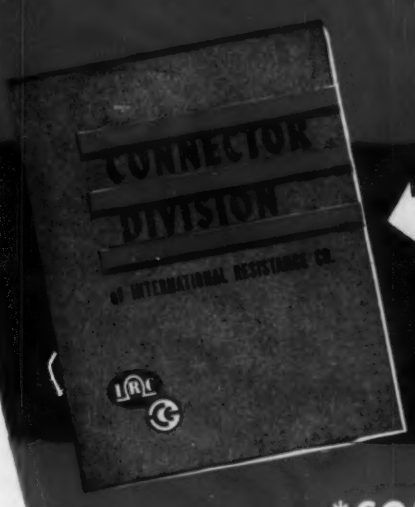

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heating a mica unit will change its its capacitance permanently; this change generally decreases the value about 5 percent, but occasionally the decrease may be as much as 20 percent.

For efficient operation in the tropics, paper capacitors should be of the metal-clad, hermetically-sealed type. Ordinary paper or cardboard-cased types are unsuitable for use in the wet tropics because they quickly develop excessive leakage resistance. While paper tubes which are properly wax-impregnated will keep out moisture, the solid wax and seals used in many early types are not adequate to protect the dielectric of the capacitor.

A tubular capacitor may be tropic-proofed by being placed in a second tubular casing of metal and then dipped in a potting-type compound which will not fracture easily when solidified.

Paper labels encourage the growth of mold and the accumulation of moisture. It is better to mark the value with paint or ink.

Resistors

Resistance values of carbon-type resistors which are not hermetically sealed usually increase slowly with time and eventually the resistors become open. Resistors of the type which are encased in molded material can be treated effectively with impregnating compounds.

To ensure good operation and to prevent breakdowns, resistors carrying current should have a wattage rating at least four times that called for under normal conditions.

Wire-wound resistors on glazed ceramic bases hold up better than wire-wound types built on organic materials which are very susceptible to fungus growth. Failures in wire-wound resistors are generally caused by corrosion and by other factors which affect fine wire coils in general. Practically all low-wattage resistors can be impregnated successfully with a sealing compound. Here again paper labels should be avoided.

Carbon-type potentiometers operating in the tropics have a tendency to become noisy and to develop dead spots. Frequent cleaning and drying is thus re-

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The use of high frequency preheating in the molding of phenolic materials has opened up a completely new field especially in heavy duty materials that is a *natural* for Durez compounds. The principal advantages of this method consist of (1) a reduction in the molding time cycle and (2) a better molded product with greater density, improved electrical properties and a more uniform cure.

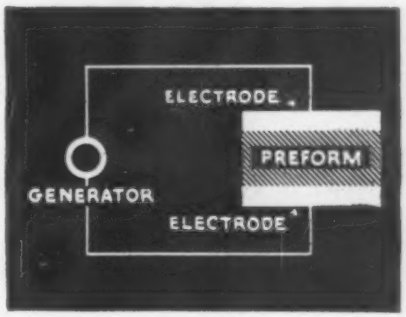
The illustration at left serves as an excellent example of the successful application of high frequency preheating in the production of a molded plastic part. The item pictured is a terminal board for military use which was molded from a preform of high-impact macerated-fabric-type Durez phenolic molding compound.

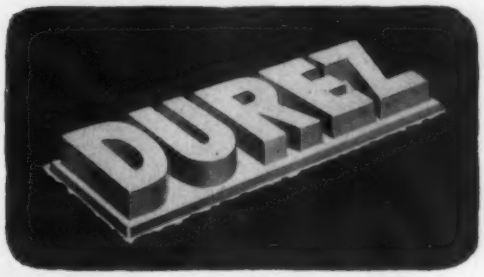
The basic operation of all high frequency preheating is shown in the simple diagram at right (notice the preform in position between the high frequency electrodes). Since the preform is never a perfect non-conductor, some leakage takes place through it. This leakage current manifests itself in the form of heat and thus the preheating of the preform takes place quickly and thoroughly. This method of preheating is particularly valuable when the preforms are of unusually thick, heavy duty material.

The use of high frequency preheating in the molding of plastics is still in the process of development and therefore is extremely limited at the present time. However, the fact that its usage results in a reduction of the molding time cycle and a better product, seems to indicate that it can be viewed as one of tomorrow's certainties.

This is but one of many developments in which Durez phenolics fill the bill. Because of their excellent dielectric properties, inertness to solvents, resistance to impact, high heat, climatic changes, mild acids and alkalies, Durez versatile phenolics have found a place in practically all fields of industry.

Perhaps there is some question in your mind about the inclusion of plastics in your post-war plans. Why not get a competent answer to that question now? Our staff would welcome the opportunity to discuss any plastic material problem with you. Durez Plastics & Chemicals, Inc., 89 Walck Road, North Tonawanda, N. Y.





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ALLIED RADIO

quired. Provision of adequate ventilation is another help; units without covers often exhibit better operation and longer life. Wirewound potentiometers used in current-carrying circuits suffer corrosion of the winding and of the sliding arm. Potentiometers of this type must be cleaned periodically. Filling with white vaseline improves their operation and prevents failure.

Insulators

In the damp heat of the tropics, ordinary sheet fibers and materials which absorb moisture will warp and yield. This characteristic, together with differential expansion, will result in misalignment of component assemblies and will cause changes in circuit constants.

For use in the wet tropics, insulating materials in sheet, block or molded form should be of phenolic composition which resists moisture. Acrylate and methacrylate resins are fair insulators and may be used in low-frequency circuits where a very high dielectric constant is not required, or where it will not be subject to extreme heat. Since this material generally can be obtained easily around airfields in scrap form it is often used to replace defective insulation.

Whenever plastic insulating material is cut or drilled, the edges of all holes and cut surfaces should be buffed and then sprayed or brushed with insulating varnish or lacquer. This treatment will prevent moisture absorption and prevent the support of fungus growth.

Wiring

The use of hook-up wire having rubber or cotton insulation should be avoided. Cotton braiding, even if waxed, will absorb moisture. If an organic wax is used, fungus growth will attack it. Even non-susceptible wax impregnation disappears in time and decomposition of the cotton will eventually result. Hook-up wire with Neoprene insulation in place of rubber, and wire with Celanese or Fiberglas insulation in place of cotton, are suitable.

When high-impedance leads are involved, surface wiring is more satisfactory than wiring laced into harness cables. If wires must be laced into forms, the lacing

NEW INSULATOR DESIGN POSSIBILITIES FOR RADIO

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The metallic film can be applied to the surface of insulators to eliminate corona effect. The use of this combination permits improvement in the design of airplane strain and lead-through insulators.

The addition of a thin metallic surface film also permits soldering of metal parts directly to the steatite insulators. Water-tight seals may be made in this manner where temperature ranges encountered in service are limited.

Your inquiry regarding *Silver Surfaced Steatite* is invited.

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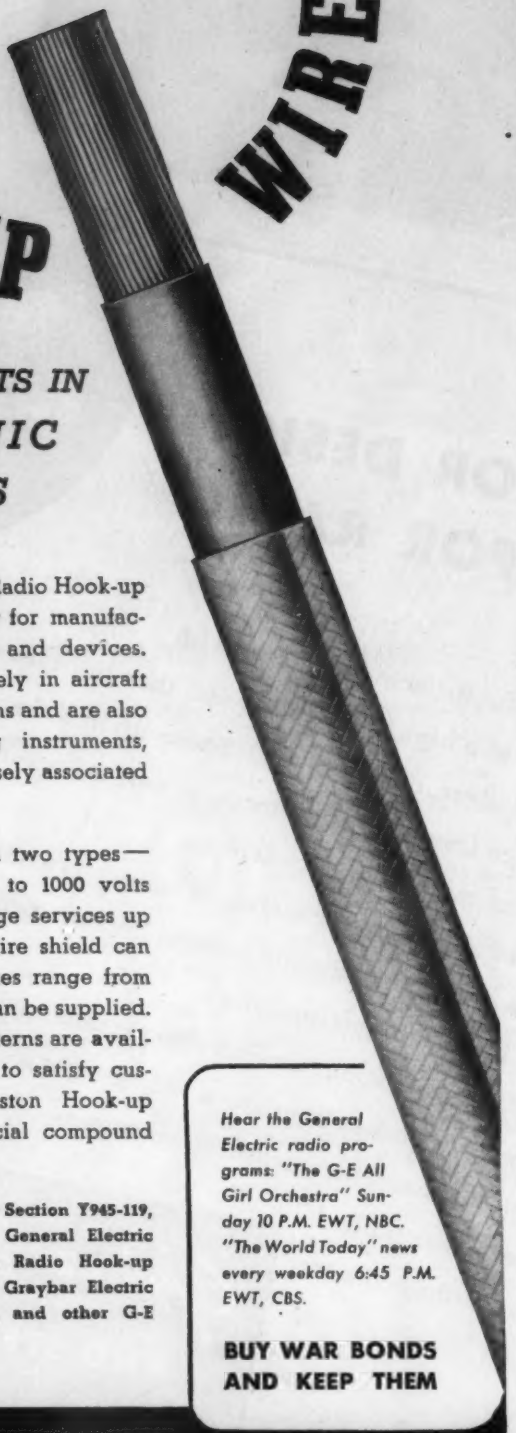

FOR ALL CIRCUITS IN ELECTRONIC DEVICES

General Electric Deltabeston Radio Hook-up Wires are designed specifically for manufacturers of electronic equipment and devices. These wires are used extensively in aircraft radio and communication systems and are also ideal for electrical measuring instruments, ground communications and closely associated applications.

Deltabeston is constructed in two types—No. 57376 for low-tension, up to 1000 volts and No. 57371 for higher voltage services up to 3600 volts. Tinned copper wire shield can be supplied in either type. Sizes range from 22 through 6 and larger wires can be supplied. Twenty-one standard braid patterns are available. Others can be furnished to satisfy customers' requirements. Deltabeston Hook-up Wires are treated with a special compound to inhibit the growth of fungi.

For additional information write to Section Y945-119, Appliance and Merchandise Dept., General Electric Co., Bridgeport, Conn. Deltabeston Radio Hook-up Wires are distributed nationally by Graybar Electric Company, G-E Supply Corporation, and other G-E Merchandise Distributors.

Hear the General Electric radio programs: "The G-E All Girl Orchestra" Sunday 10 P.M. EWT, NBC. "The World Today" news every weekday 6:45 P.M. EWT, CBS.

BUY WAR BONDS AND KEEP THEM

GENERAL ELECTRIC

materials should be waterproof and inorganic in makeup so that it will not support fungus growth. Bindings should not be drawn more tightly than is required to support the form.

In general, solid wire will hold up better than stranded wire for surface wiring. When dressing wire at terminals, care should be taken not to bend sharply, stretch, dress and redress lacquered or varnished wire unnecessarily; otherwise, the coating may crack and the insulation will absorb moisture. Wiring should be as straight as possible; bunching or knotting must be avoided. Fungus growth is heaviest where wires are crowded.

Plugs

Condensation attacks plugs; moisture gets inside, runs down on cables and is often the cause of failure due to electrolysis and final shorting of leads. Holes could be provided in the bottom part of the plug to drain off water.

Batteries

Dry cell batteries have a very short life in the wet tropics. Satisfactory service has been obtained from those in which both inner and outer cases are well impregnated with wax or sprayed with a moistureproof coating.

Batteries which are mounted in cases should be well screened and separated from metal surfaces by a liner of high-quality moisture-resistant insulation. The battery case should not be allowed to come in contact with metal at any point, even though the battery case appears to be well-impregnated with wax. This precaution is especially important where fairly high wattages are used.

In the field, the life of dry cell batteries is prolonged by repacking them in tins—eight cells to a tin—and soldering the tins airtight. The batteries are left in the tin until needed.

Dynamotors

The failure of dynamotors has been reported in which the cause has been found to be the high-voltage output shorted to the case because of exposure of wire insulation to excessive moisture. Where there is excessive leakage,

ONE ALWAYS STANDS OUT

IT'S THE QUALITY OF PERFORMANCE THAT COUNTS

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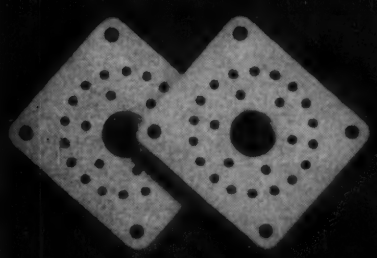

Where stability is an important requirement, ALSIMAG Steatite ceramics are unsurpassed for lending rigidity and permanence of alignment to electronic circuits.

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3 basic contact arrangements

single-circuit, normally open

single-circuit, normally closed

double-circuit, one normally open and one normally closed

And many special forms. For example:

three-point structure

single-break, normally open

single-break, double-throw

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(This one is ACTUAL SIZE)

WHEREVER you need a tiny contact mechanism in ratings up to 10 amperes at 24 volts d-c—an enclosed, self-contained unit that's light and compact, yet can withstand thousands of operations—there's a G-E Switchette to do the job.

This tiny switch weighs only 9 grams, and is suitable for use at altitudes up to 50,000 feet and in ambient temperatures from 200 F to −70 F. It's corrosion-proof—meets 50-hour salt-spray tests. It's vibration-resistant. The contacts will not chatter when subjected to mechanical frequencies of 5 to 55 cycles per second at 1/32-inch maximum amplitude (1/16-inch total travel), or to a linear acceleration of 25 g in any direction.

Two terminal arrangements are available—out the ends of the case as shown above, or out the top through the cover. This makes for easy mounting in any position.

More than 200 design modifications of the G-E Switchette are available to provide for a wide variety of electrical and mechanical arrangements.

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arc-over will occur and the armature winding will burn out.

Occasionally, the insulation will test satisfactorily during a later inspection if the equipment dries out, but failures will recur whenever the same conditions of previous failure exist. The best way to eliminate such failure is to replace the insulation and to rearrange the high-voltage lead so that it is kept away from the dynamotor case and other areas of ground potential.

Test Instruments

In panel-type meters, corrosion attacks the leads to coils, especially near newly soldered joints. It also attacks the pivots and armatures in meters which are not properly sealed.

Varnish or lacquer must be used to seal test instruments after they have been opened for repairs or for any other reason. Meter glasses should be sealed to the case, and other openings, such as screw holes and terminals need attention. Edges of the back panel require sealing with tape and varnishing over. The zero-setting adjustment screw is often a big source of trouble because it allows moisture to get in. After each readjustment, it must be painted over with varnish or lacquer.

Even after applying these measures, test instruments will still fail under conditions of high humidity. It has been found practical to keep ohmmeters and other test instruments in heated storage boxes with batteries removed when the instruments are not in use.

• • •

Electronic Indicator for Detonation

By E. A. TRAVER

General Laboratories
Socony-Vacuum Oil Co.

THE DEVICE whose circuit is shown in the diagram is essentially a detonation or knock indicator which was especially designed to indicate the intensity of the knock occurring in an automobile engine when determining the octane number of a gasoline. The conventional sound level meter and sound analyzer cannot be used for this purpose because of the transient nature of the sound.

Engine knock is a sound of short duration which dies out rapidly and

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6EC600	6.0	600	4	2
6EC800	8.0	600	4½	2
6EC1000	10.0	600	4	2½
10EC100	1.0	1000	2¾	1½
10EC200	2.0	1000	4½	1½
10EC400	4.0	1000	4	2
10EC600	6.0	1000	4	2½
10EC800	8.0	1000	5	2½
15EC50	.5	1500	2¾	1½
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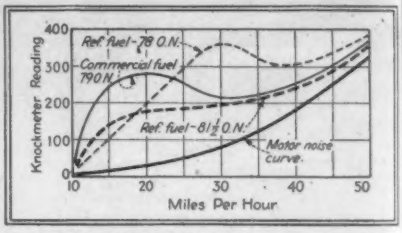
recurs at varying time intervals. Also, the sound intensity tends to vary with each recurrence. This instrument is used as a comparator for indicating the relative knock intensities produced by two different fuels, instead of measuring the knock intensity of each fuel on an energy scale.

The knock comparator consists of the following elements: a microphone, vacuum-tube amplifiers, filters, a vacuum-tube detector and an indicating meter. All the parts, with the exception of the microphone, are built into a portable metal case which contains the necessary batteries and also serves as a shield to prevent interference from the engine ignition system.

Operation

The sounds of knock and other engine noises are picked up by a microphone which is mounted in the engine compartment. The microphone is sensitive to all the sounds between 40 and 10,000 cycles per second occurring in the engine, which includes the transient sound of knock or detonation. The electrical output of the microphone is



Typical knockmeter curves of unknown and reference fuels during acceleration of a 1939 Oldsmobile automobile

passed through several stages of amplification and then impressed on the grid of a vacuum-tube detector. A variable bandpass filter is interposed between the stages of amplification to eliminate engine noises of lower and higher frequency than those comprising knock. The frequency of the filter to be used is determined by experiment and varies with different engines. The detonation or knock usually has a frequency between 4000 and 7000 cycles per second.

The detector circuit uses such values of capacitance and resistance that the effect of the high intensity knock sounds are maintained for a period many times longer than their own duration. The time constant of the capacitor-

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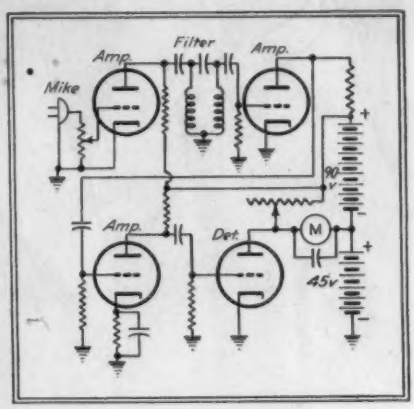
resistor combination is made somewhat longer than the expected interval between successive detonations so that the average voltage on the grid of the detector tube depends upon the more intense detonations while other sounds of the same frequency have very little effect. In this manner, the instrument tends to indicate an average of the loudest detonations and not an average of all sounds occurring at the filter frequency.

The meter circuit has been designed so that a decrease in current through the detector tube, which is caused by an increase in knock intensity, will be indicated as an increase in meter reading. In order to make it possible to read the intensity accurately, the meter is damped so that it averages the knock indication for a somewhat longer period of time than the detector tube circuit. The variable resistor in the plate circuit of the detector permits setting the meter to zero at any level of sound intensity.



Circuit of the knockmeter used to show the relative intensity of two fuels

The automobile is operated with a non-knocking fuel under normal conditions to determine the noise level incident upon such operation. This operation may be expressed by a curve as shown in the graph. If investigations of knocking at a single speed are to be made, only the noise level at that speed need be determined, but in the usual case, knocking over an acceleration range is investigated. Then the auto is operated under knocking conditions and the meter adjusted to give a center-scale reading at the conditions of knock encountered. This adjusts the meter to the motor with which it is to be

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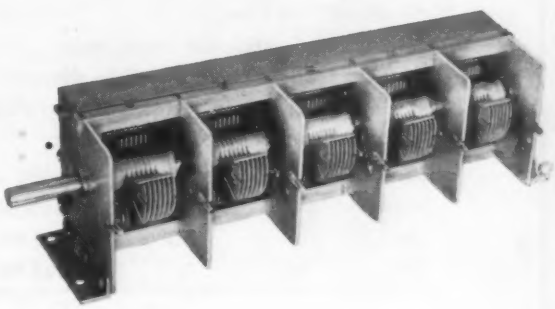

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used in the contemplated test.

The knock indicator, when properly adjusted for the car engine and test conditions, will indicate knock intensities in much smaller increments than can be detected by the ear. The instrument will also reproduce the knock intensity comparison much better than the same observer on successive trials or on successive days.

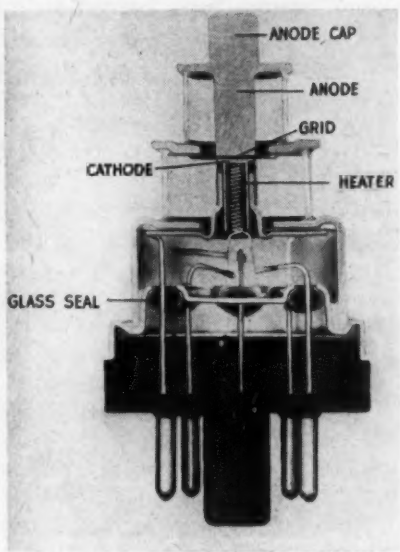
• • •

Secret Military Tube has Elements in Parallel Plane

A LARGE NEW FAMILY of uhf electronic tubes, circuits and apparatus has been made possible by the invention of an electronic disc-seal tube, called the "light-house tube," by radio engineers in the military services. The existence of the new tube, was acknowledged publicly early in April when General Electric was allowed to disclose that the tubes are available to make possible radio relaying of television and f-m radio programs post-war. Beyond that, no further information could be revealed.

The Army and Navy have now approved the release of further information on the tube, including the fact that it has given the Allies a decided edge over the Axis in the military radio field.

The new tube eliminates the conventional type of grid anode and cathode. Instead of components being fitted around one another as in the past, they are now constructed in simple, parallel planes or layers,



Cross-section of the new uhf tube used in military equipment

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PLANNING a new or improved device of small size that will need low torque power? Then you're going to need motors that will deliver it, smooth as velvet, with instant starting, quick pick-up and reliable operation.

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VERY LIKELY the motor you'll need will come from our long line of standard *Smooth Power* motors. But if not, we can adapt a standard model or design a new one for your specific needs.

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MODEL 220
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MODEL 402
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This enormous range of voltages—five hundred million to one—is accurately covered by our Model 300 Electronic Voltmeter and some of the accessories shown above. Frequency range 10 to 150,000 cycles. Accuracy 2% over most of the range. AC operation. Five decade ranges with logarithmic scale make readings especially easy. Uniform decibel scale also provided. May also be used as a highly stable amplifier, 70 DB gain, flat to 150,000 cycles.

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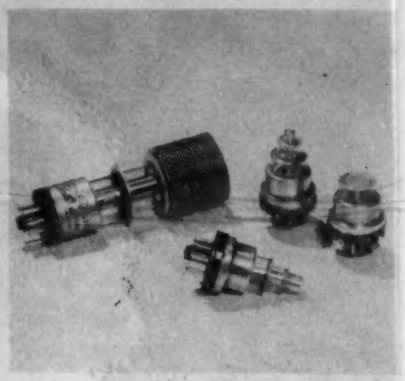
BOONTON, NEW JERSEY, U. S. A.



Four of the hitherto secret tubes having the disk-seal construction. The one at left is a transmitting tube, the others are receiving types

with glass and metal fused together in rigid, inseparable units that are strong and capable of withstanding severe jolts. This design permits an extremely compact over-all tube structure, while providing high frequency and high power output. It gives uniform co-planar electrode design, very low plate-to-cathode interelectrode capacitance, and very high permanence of characteristics. Megatron is the generic name applied to tubes of this design.

General Electric's development was made available to Allied private and government research and engineering groups. The Naval Research Laboratory and the Camp Evans Signal Laboratory of the Army were among the government groups which actively engaged in the early applications of the new development.

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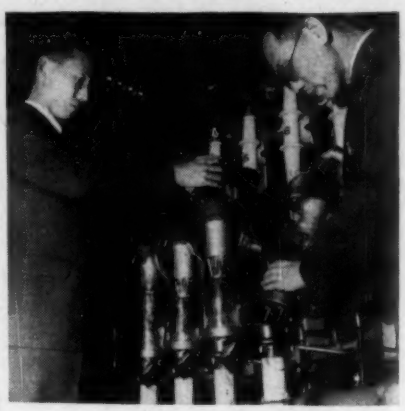
CHINESE TRANSMITTER

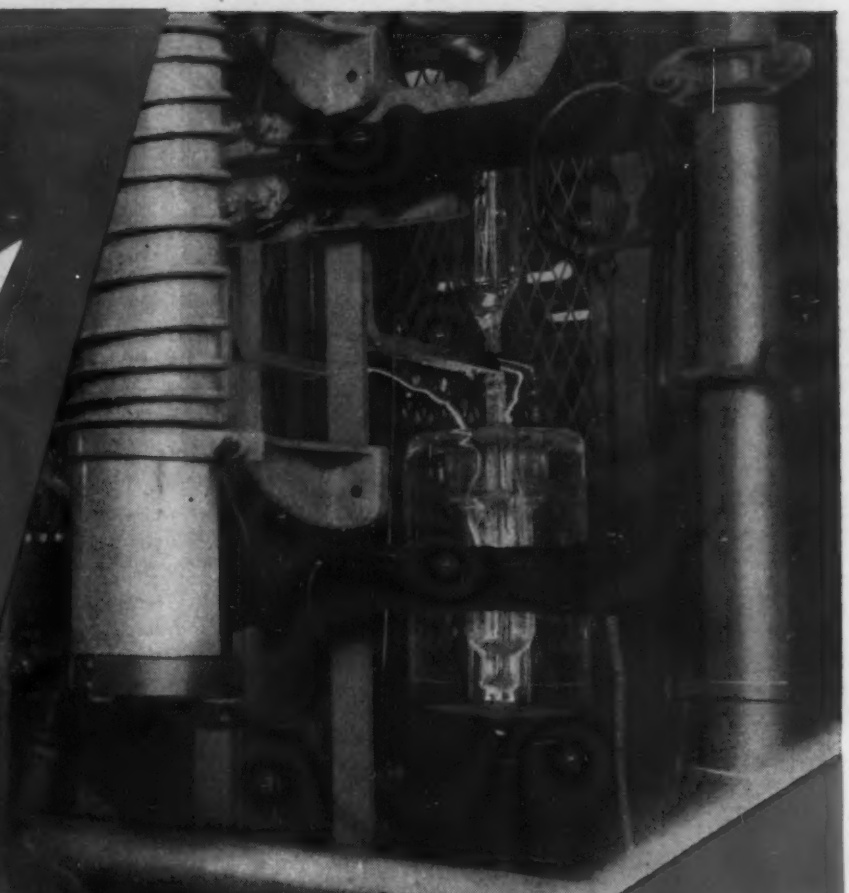


Two engineers from the Chinese Central Broadcasting Administration fit tubes into the rectifier unit of a high-power broadcast transmitter recently built in Great Britain for China

Federal Tubes...

come CLOSER to the

PERFECT VACUUM



Here is one of the double aisle exhaust banks where 16 high power tubes can be exhausted at one time, each with individual control.

Always in the forefront of tube research and development, Federal makes another advance and now has added exhaust units of entirely new and original design to its production equipment.

This latest Federal achievement produces a tube that is substantially closer to the perfect vacuum—a tube with greater efficiency and longer life.

Arranged in banks of eight and operated with identical control equipment, these units exhaust uniformly every size of Federal tube—assuring a consistent and high standard of quality.

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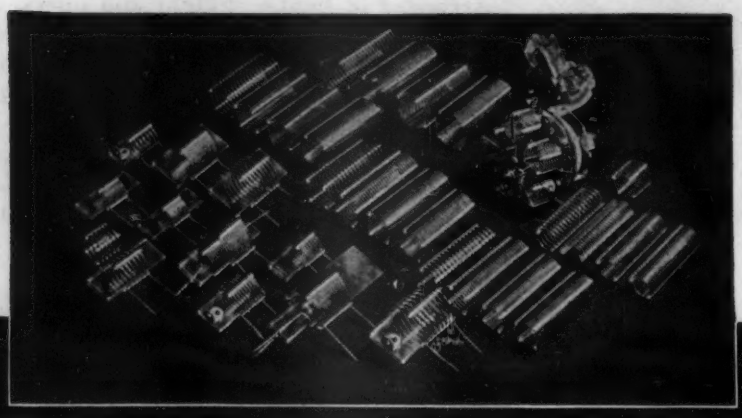

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Control of Stills

(*Continued from page* 99)

twice the values indicated. The optimum value is determined by the current requirements of the control cell connected between T_1 and T_2, and its maximum resistance. In any event, the sensitivity is influenced by the potentiometer setting.

When adjusting the unit, should the gas tetrode fail to conduct with the potentiometer set for maximum bias and T_1 and T_2 connected together through the control cell having its electrodes immersed in single-distilled water, the bias is reduced until conduction does take place. In the event that the tetrode conducts with the control circuit open and with the potentiometer set for maximum bias the value of C_1 is increased. A shield for the lead connecting the grid and the control cell has been found necessary in applications where considerable sensitivity is required.

Limiting resistor R_5 is selected to limit the surge current to the rated value. The two resistors, R_5 and R_6, limit the average current to that required for reliable operation of the plate circuit relay. Capacitor C_2 must be of sufficient capacitance to smooth the relay current for noiseless operation. Where variable conditions are present in the control cell, relay chatter can be reduced by increasing the value of C_2 as much as space factors permit.

The circuit described has the usual advantage over similar hard-tube circuits in that the gas tetrode will close the plate circuit relay with no uncertainty if it closes it at all, regardless of some abnormal behavior of the control cell. The circuit described has been in operation without a single failure for nearly one year. No adjustments beyond those made during the original installation have been required.

Some System Refinements

In some applications better performance may be obtained by connecting the grid lead to one side of the control cell rather than to the other. The control cell used in the present application, shown in Fig. 3, consists of a tubular unit with two platinum electrodes extending down to the level which determines

Type RT Thermostat. Adjustable Temperature Control.

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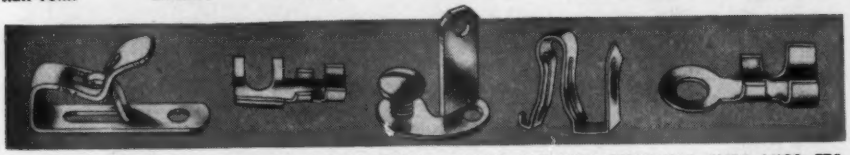

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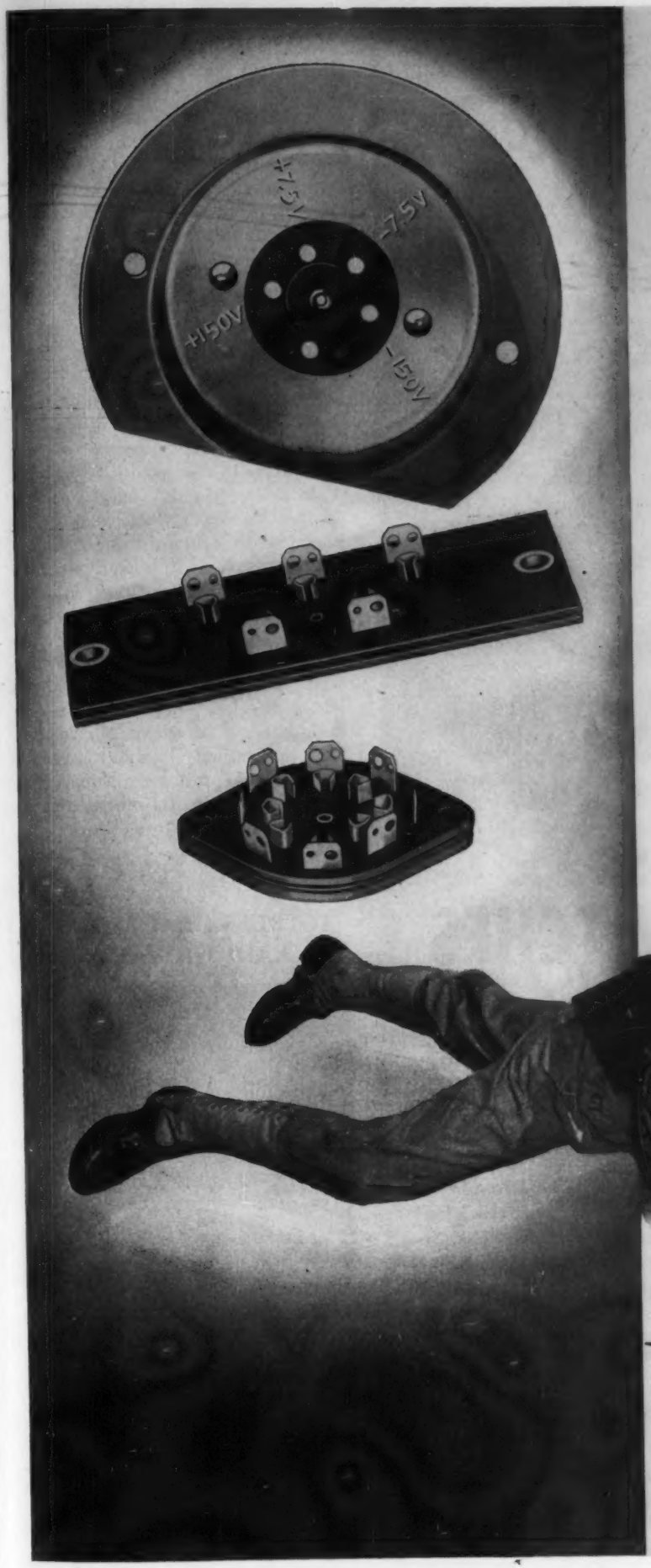
the minimum level of the water in the boiling flasks. It has been found advantageous to set the electrodes at slightly different levels, with the grid connected to the higher one. Electrolysis in the control cell has produced no difficulties, probably due to the use of a. c. in the control circuit and the exceedingly small currents flowing.

The solenoid valve is placed in the water line leading from the single-distilled water storage tank to a reservoir and the control cell. The reservoir was added in order to lengthen the period between successive operations of the system. Since it is the minimum level that requires control rather than the maximum level, it is preferable that water be added in relatively large amounts at infrequent intervals rather than in small amounts at frequent intervals. The amount added is controlled by a self-starting siphon in the reservoir and by the rate of flow from the reservoir to the control cell. By partially filling the connecting tube between reservoir and control cell with glass wool the rate of flow may be adjusted to the point where the reservoir fills just as the water level in the control cell reaches the electrodes and closes the electromagnetic valve. The glass wool restriction also serves to damp out level fluctuations due to boiling action as the water level approaches the operating point.

The sensitive electronic relay controls simultaneously the valve and electric heater circuits, opening the valve and turning off the heaters whenever the system calls for water. In the event that the single-distilled water tank becomes empty, or the valve fails to open, or any other condition prevents the normal supply of water, the still heaters are shut off. Similarly, most failures in the control itself will result in opening both the heater and the valve circuits, thus effectively turning off the stills. By inserting a time-clock switch in the line side of the control circuit the system may be set to operate automatically for a predetermined time.

The heater system as installed originally was provided with a three-phase electromagnetic switch operated from the usual "off-on" pushbutton station. To give the electronic unit control of the switch with a minimum amount of rewir-



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ing, and to retain the original push-button station, a simulated push-button station, relay-operated, was devised. This station consists of a solenoid contactor in combination with a mercury switch. The mercury switch is fixed to the contactor armature in such a position that the closing of the contactor causes the mercury to flow toward the end of the tube into which the contacts are sealed; however, the closed position of the contactor is such that the globule of mercury does not remain across the contacts. Closing of the circuit is dependent upon the inertia of the moving globule carrying it past the equilibrium position to make momentary contact before returning to the position of rest. This action simulates the pushing of the "on" button. Release of the armature by a signal from the automatic control unit is equivalent to pushing the "off" button.

In addition to its use in the still system, the electronic relay described has been found ideal for use with sensitive thermo-regulators whose precision depends upon the maintenance of clean contactors. The exceedingly small currents drawn by the unit permit operation for long periods of time with mercury thermoregulators.

• • •

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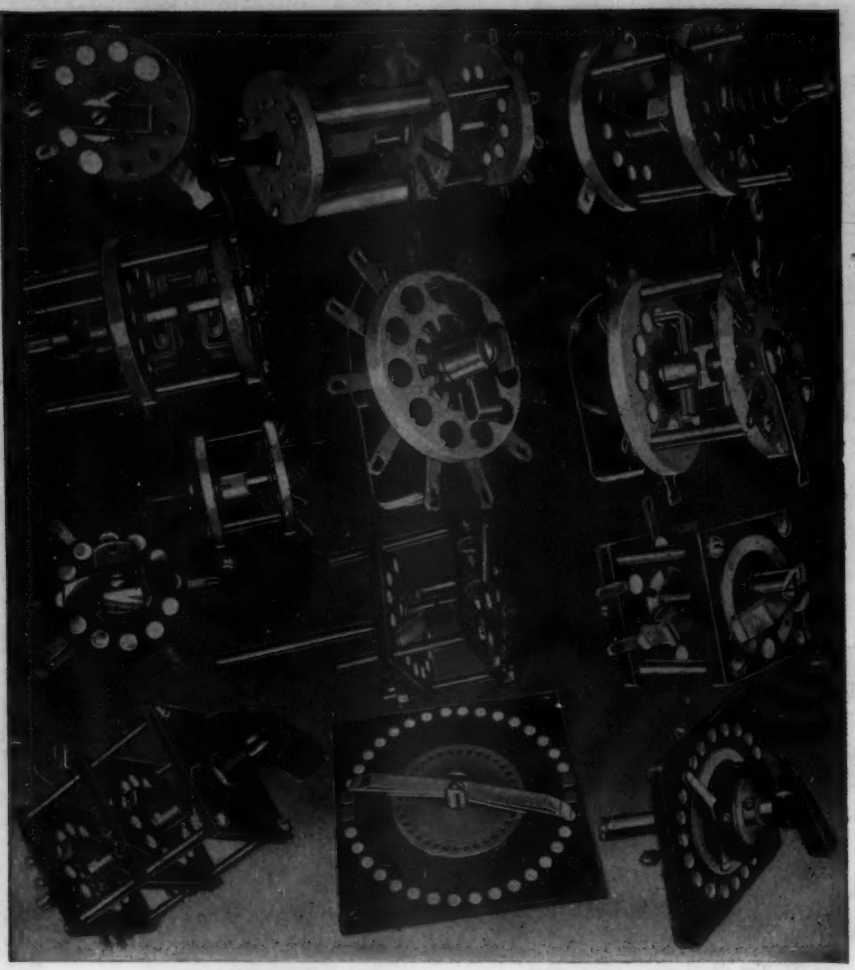
Virginia Robinson, Broadway actress, broadcasts messages over a U. S. Army radio net in Italy to German soldiers. She went to Italy to entertain Yankee and Allied troops; instead her excellent German was used to make propaganda speeches between musical numbers



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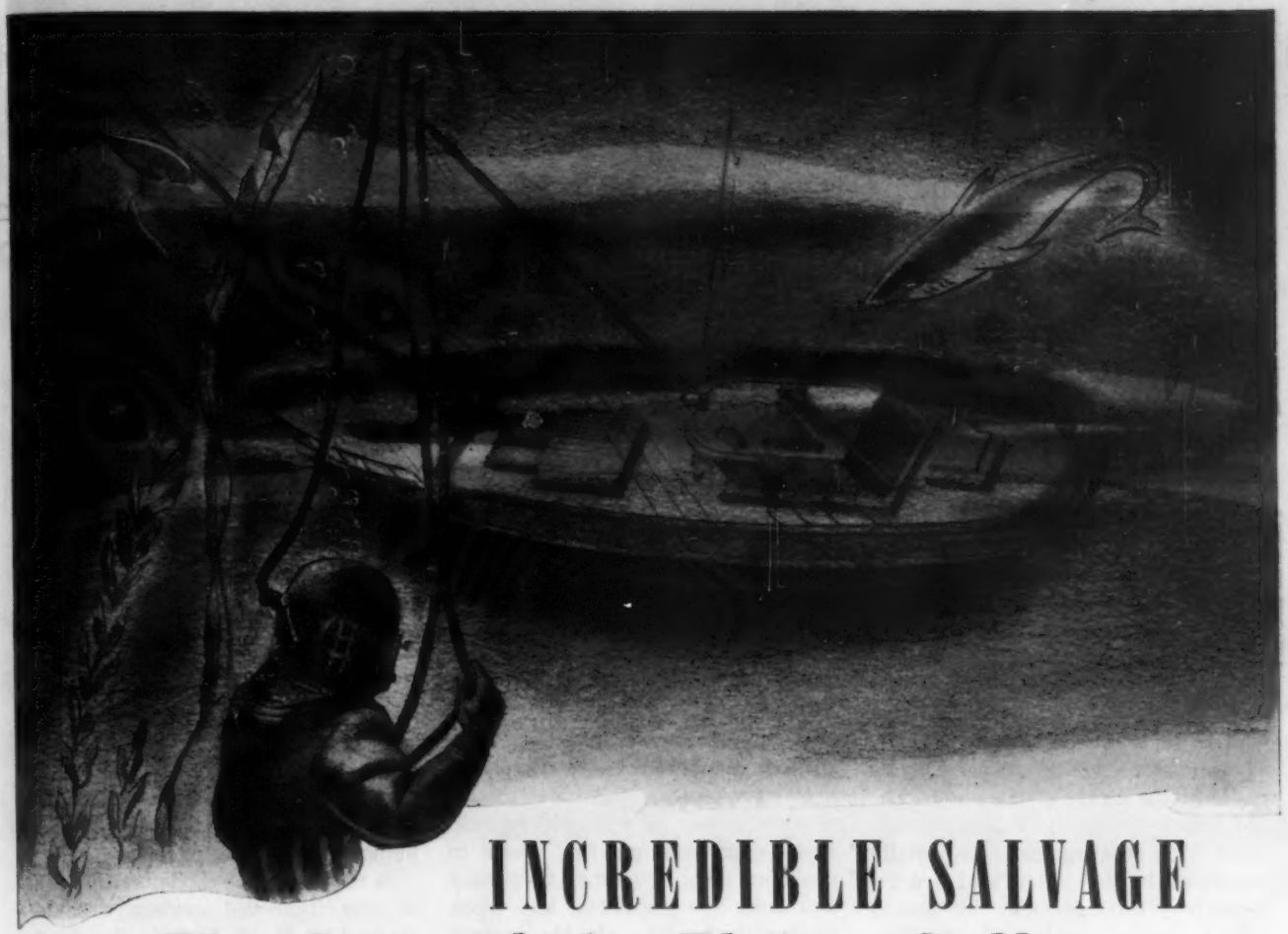

INCREDIBLE SALVAGE

The Case of the Flying Gull . . .

During the storm season of 1942, *The Flying Gull* ran into heavy seas in the Gulf of Mexico.* Running before a terrific wind, she all but made port. Then, just as she was putting about near Hunter's Point, she shipped a gigantic wave and foundered. All hands were saved. But *The Flying Gull* rested in eight fathoms of Gulf water.

Salvage operations were started. Later in 1942, when The Flying Gull was in the dock and her electrical equipment ripped out, an amazing thing occurred. George Long, of The Harris Salvage and Drydock Company of Galveston, put the Thermador transformer equipment on a shelf in the sunshine—mentally assigning it to the scrap metal drive. Three days later, out of curiosity, he hooked the transformers onto a testing bench and flipped on the current. To his amazement, they still showed signs of life. He then ran standard tests. To his further astonishment, all twelve of the transformers were not only working—they were working perfectly.

Harvy Stark, owner of the boat, had already ordered a complete new set of transformers from Thermador. He cancelled the re-order. And today The Flying Gull sails with her original Thermador transformers. Not designed for the briny deep—but they could take it!

Such stories of plus performance are not accidents, for Thermador transformers are built to perform beyond normal expectations. They are completely manufactured—not just assembled—under one roof on a vast array of modern precision equipment. They are made *only* from the finest materials, engineered by men of broad experience. The result is not alone quality but *quality in quantity*. If that meets your specifications, better discuss transformers with Thermador.

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"SEVEN LEAGUES AHEAD"

An actual case history from Thermador files; however names, dates, and location have been altered.* **Buy MORE War Bonds.

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THE ELECTRON ART

New Rotating Slide Rule with 24 Scales on Slider 252

Amplitude Control for Variable-Frequency Oscillators 252

Electronics in AIEE 265

New Rotating Slide Rule with 24 Scales on Slider

A ROTATING SLIDE RULE that permits a wide range of applications by electronic and electrical engineers has been invented by Lt. Jerry Ailinger, communications officer of the Boston Fire Alarm Headquarters. Called the "Rota-Vec-Trig," the new rule is designated as a log-log, vector and trigonometric slide rule.

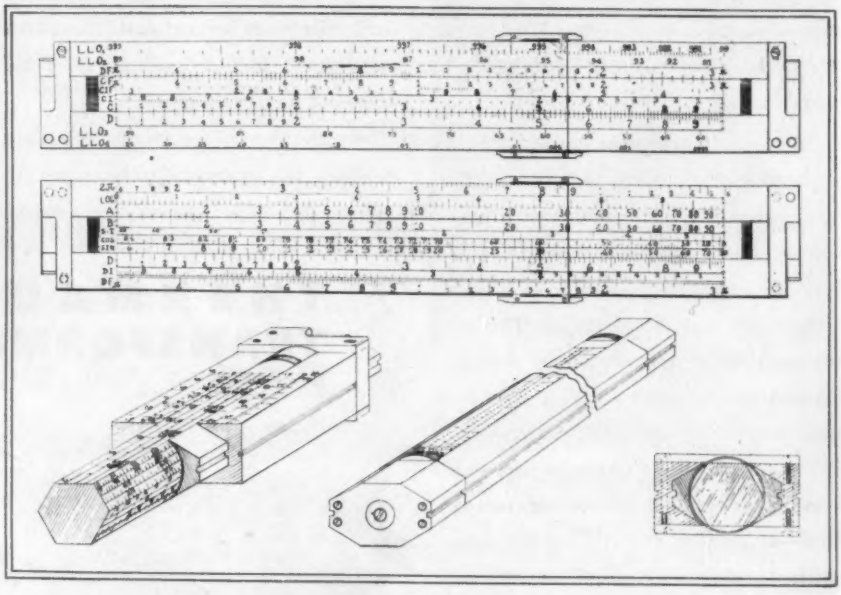
In appearance, the instrument resembles the ordinary slide rule, but contains 24 scales on its slider, compared to a maximum of eight on usual rules. All 24 scales operate against each side of the body. The 24 scales are grouped four to each face of a rotating hexagon axially mounted in the slider, and are instantly interchangeable by means of a milled wheel protruding slightly from the rule face. The selected scale locks in place when the plane of the scale is flush with the rule surface.

These scales are rotatable through 360 deg, which permits all 24 scales to slide against each side of the rule body without removing the slider to turn it over. The rotating hexagon, due to the great amount of space available, has scales representing the six leading functions of trigonometry, thus eliminating the need of converting certain functions by a primary solution involving identities, reciprocals, etc.

Rewriting a problem for slide rule solution is practically eliminated. The provision of scales of tangents greater than 45 deg and cotangents less than 45 deg allows the computation of tangents of any magnitude by the basic formula arc tan $\theta = a/b$, rather than by reciprocal form, where a/b is greater than 1. Complements are present when needed.

All scales except A,B and KS are of full unit length for greater accuracy and ease of operation. The KS scale is like the K scale on other slide rules, but is on the slider. It provides automatic cube root extraction regardless of the number of times the radical appears in either the numerator or denominator, and does away with the need of grouping "like radicals". Another interesting feature is a radian θ scale complementary to the C and D scales. This gives the angle subtended by N radians, or conversely, the equivalent radian value of N degrees.

A 2π scale provided is invaluable in calculating problems involving angular velocity. It gives the value of omega (ω) in a single setting. Radio engineers find this useful in problems of resonant frequency and inductive reactance, and when used with the DI scale, the computation of capacitive reactance. Another innovation is the introduction of log-log scales on the sliding section for greater flexibility. There are also new log-log scales of decimal quantities of full unit length for greater accuracy, referred to the D scale, which give the value of negative powers (e^{-n}) with a single setting. Besides folded and inverted scales on both body and slide, provision is made, when desired, for scales representing hyperbolic functions, also special scales for navigators, surveyors, chemists and other specialists.



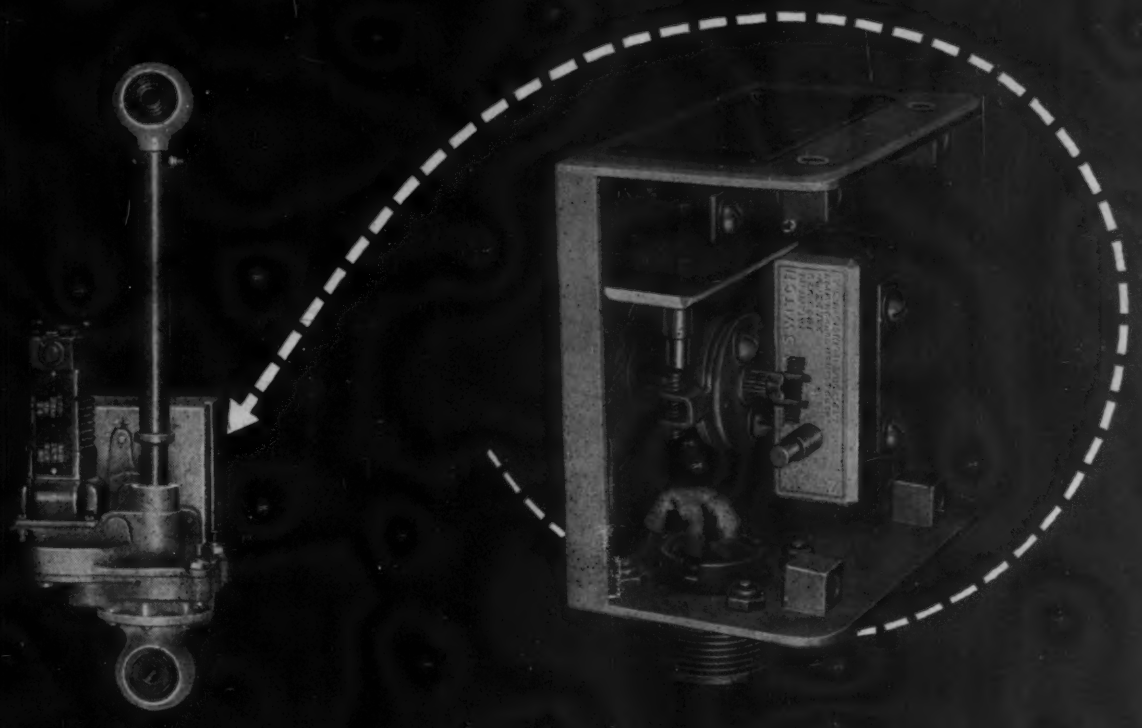
Several views of the new slide rule and its assemblies. At lower left is a section of the body of the rule, rotatable slide and housing. A cross-section is at lower right

Automatic Amplitude Control for Variable-Frequency Oscillators

ADJUSTMENT OF THE FREQUENCY of oscillators by varying the capacitance or inductance of the tuned circuit is common practice but without some stabilizing means the amplitude of the oscillation usually varies, sometimes considerably, as the frequency is changed. Means of stabilization have been suggested in the past, such as the use of a diode shunted across the tuned circuit, but while such arrangements produce some improvement, the degree of stabilization obtained is insufficient for many purposes.

A review of the diode method and a new improved system are described by M. M. Levy in the *Journal of the British Institution of Radio Engineers* (9 Bedford Square, London, W. C. 1) for March-May, 1944.

In Fig. 1 is shown the tuned circuit of an oscillator connected to a



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This small Lear Actuator shown here weighs but 3.3 pounds. Yet it is capable of moving 1200 pounds. Rotary type Lear Actuators are capable of operating torques from 400 inch-pounds to 6500 inch-pounds.

Lear Actuators must operate instantaneously. Micro Switches, used in pairs, cause the unit to start or stop at the exact point of predetermined setting in the control box. The first Micro Switch limits the actuator travel in one direction, the second Micro Switch serves as the limit to travel in the other direction. Lear Actuators may be controlled by manual switches, thermostats, pressure switches, etc.

Micro Switches were selected by Lear Avia, Inc. because a sensitive and precise limit switch was required to provide the accuracy of control necessary. The quick make-break action of Micro Switches was also found to assure long operation life on severe direct current loads. No unit failure due to faulty Micro Switches has ever been recorded.

Designers and production engineers who are letting pre-conceived ideas go by the boards . . . seeking a new way . . . will do well to investigate Micro Switch. This tiny, snap-action electric switch can be counted on for any application where a small, precise, sensitive switch is required that will respond accurately to actuating motion through millions of repeat operations.

Micro Switches provide over 2700 variations . . . combinations of housings, actuators and electrical characteristics. For complete information, send for Handbook-Catalog No. 60. If your application is for aircraft use, also send for Handbook-Catalog No. 70.

The basic Micro Switch is a thumb-size, feather-light, plastic enclosed, precision, snap-action switch, Underwriters' listed and rated at 1200 V.A., at 125 to 460 volts a-c. Capacity on d-c depends on load characteristics. Accurate repeat performance is experienced over millions of operations. Wide variety of basic switches and actuators meets requirements varying from high vibration resistance to sensitivity of operating force and motion as low as 2/1000 ounce-inches. Many types of metal housings are available.

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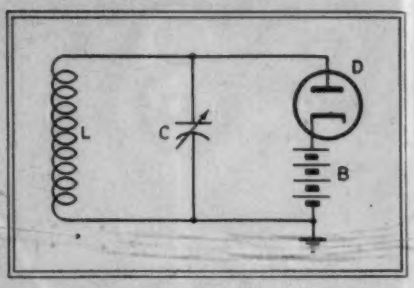


Fig. 1—Circuit illustrating the principle of stabilization of oscillator output amplitude by means of a diode

stabilizing diode *D*. The cathode of the diode is made positive by a battery *B* or other suitable means, and the biasing voltage is chosen to be slightly less than the desired maximum voltage to be generated in the tuned circuit. If the amplitude of the oscillations should tend to increase when the frequency is changed, the diode *D* will become conducting for the peaks of the positive half waves and will act as a load on the tuned circuits which increases as the amplitude increases. It therefore tends to limit the amplitude of the oscillations. However, experience shows that the stabilizing control is not very great, and considerable amplitude variations still occur.

Use of Triode

The effectiveness of the control is greatly increased by using the circuit of Fig. 2 which uses a triode to shunt the tuned circuit instead of a diode and which applies to the control grid the amplified and rectified variations of the oscillating voltage by means of the detector amplifier connected as shown. This can be most easily appreciated in the following way. Let v be a variation in the amplitude of the oscillating voltage. This will be detected and amplified and will be

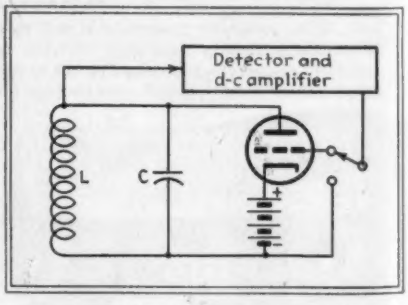
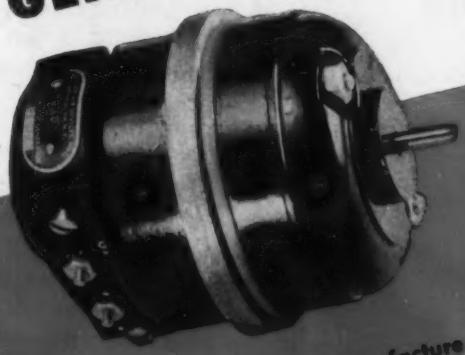


Fig. 2—Addition of an amplifier to a triode permits variations of the oscillator voltage to be detected, amplified and transmitted to the grid of the triode

PERMANENT MAGNET FIELD
DC VOLTAGE GENERATOR



We were called upon to manufacture this small voltage generator in which concentricity between shaft and mounting ring had to be within .001" while diameter of large mounting ring was held to ± .001". Output voltage was linear with speed to 1% and voltages were equal within 1% for each direction of rotation. A careful analysis of tooling requirements, together with the use of precision equipment, did the job.

Mounting ring diameter.....2 5/16"
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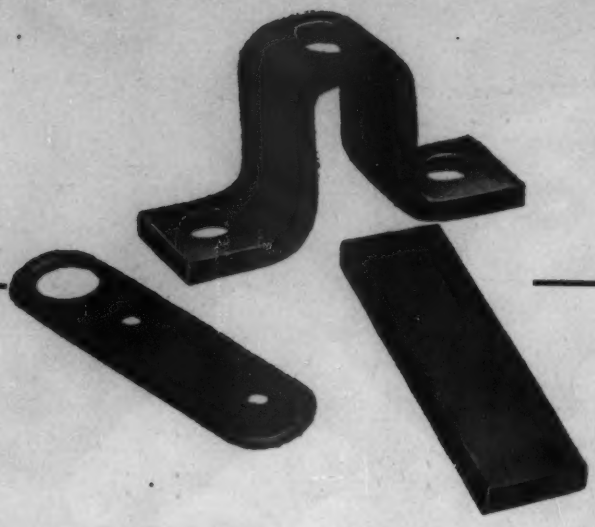

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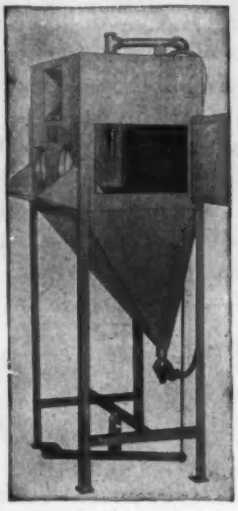

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multiplied by some factor μ_1, becoming $\mu_1 v$. This voltage is applied to the grid of the tube and produces the same damping effect on the tuned circuit as another voltage P applied to the plate and equal to $\mu_1 v$ multiplied by another factor μ_2; thus $P = \mu_1 \mu_2 v$. It is evident that a much greater load will be placed on the tuned circuit for the same value of v with the arrangement of Fig. 2 than with that of Fig. 1, and accordingly a much more effective stabilizing control is obtained. Many standard triode valves have an amplification factor μ_2 as high as 50, and μ_1 may easily be made equal to 10. A multiplication of 500 is thus obtained. The result can provide a circuit in which the variation over the whole frequency band is less than 0.05 db.

Practical Circuit

Figure 3 shows a simplified diagram of a practical stabilizing circuit in which the variations of the high-frequency oscillating voltage are detected by a conveniently biased triode D, and amplified by a direct-current amplifier VT-1.

The cathode of the diode is given a positive bias by battery B_1, the voltage of which should be just slightly less than the minimum

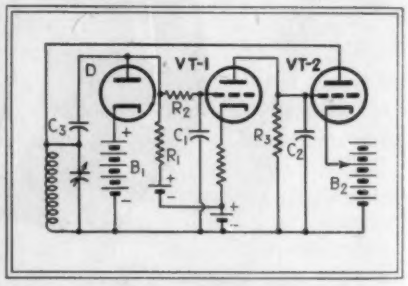

Fig. 3—Output voltage of the diode is amplified by VT-2 and applied to VT-3 operating as an amplitude limiter

amplitude of the uncontrolled oscillating voltage in the tuned circuit, taken over the whole frequency range of interest. The diode will accordingly tend to produce a rectified output voltage in the load resistance, R_1, proportioned to the excess amplitude. This voltage is smoothed in the circuit comprising the resistance R_2 and capacitor C_1, and applied to tube VT-1 arranged as a direct current amplifier, producing an amplified continuous voltage across the load resistance R_3 shunted by the bypass capacitor C_2,

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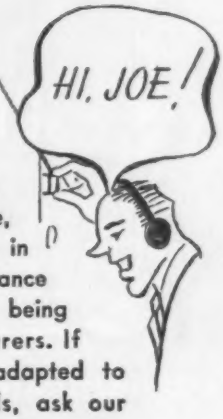

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and is applied to the control tube VT-2 which then operates as a very sensitive amplitude limiter.

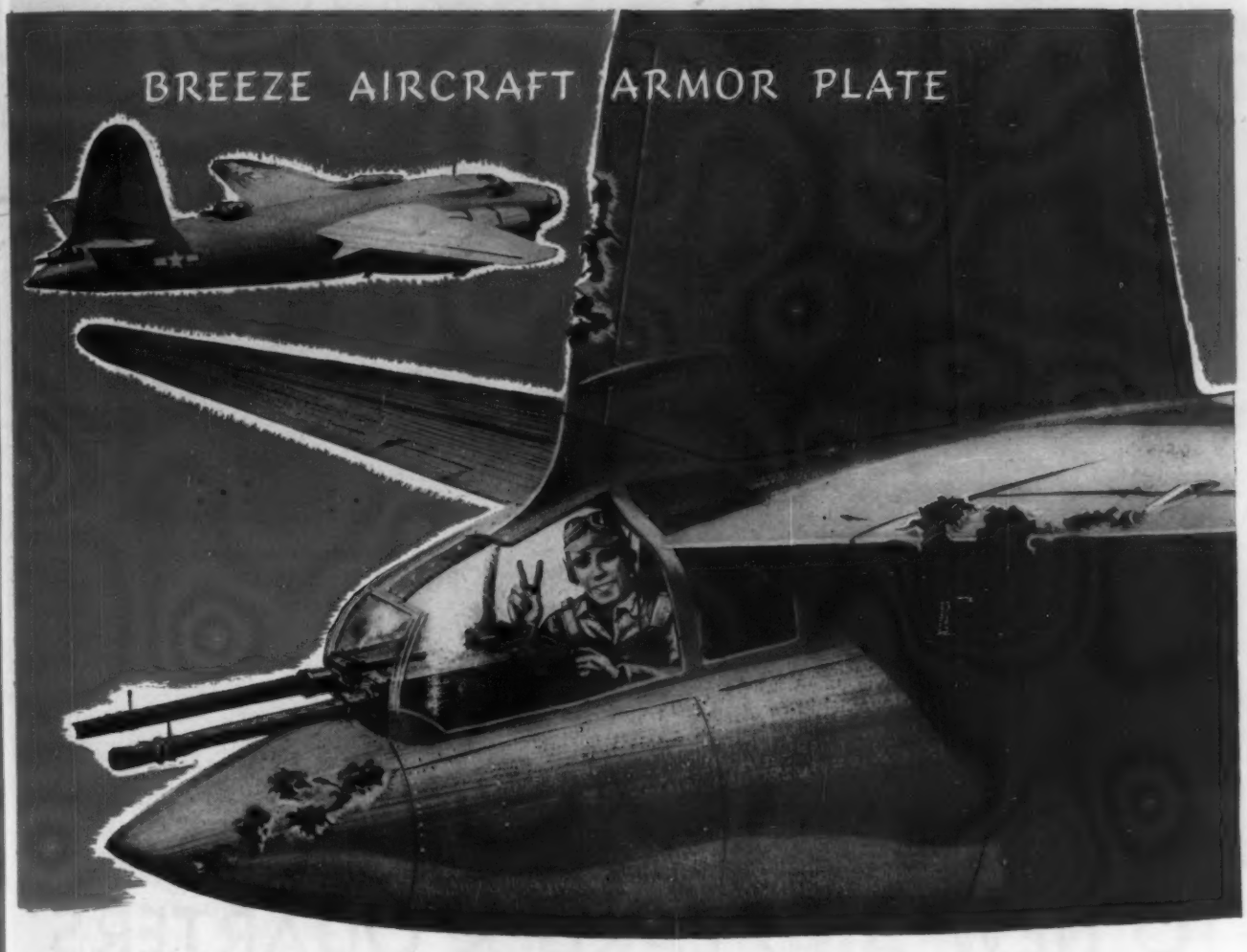
Any increase of the oscillating voltage across the tuned circuit produces an equal negative voltage across capacitor C_2 and C_1 and a much greater voltage increase at the grid of VT-2. This greatly increases the load across the tuned circuit and reduces the oscillating voltage to very nearly its initial value.

The cathode of tube VT-2 is biased positively by suitable means shown as a battery B_2, the voltage of which should be adjusted in order that the current flows in VT-2 only during the positive peaks of the oscillating voltage. When the adjustment is correct, the oscillating waveform becomes sinusoidal with a very small percentage of harmonics.

Another Circuit

The circuit of a practical arrangement with which the method has been tested is shown in Fig. 4. This circuit is slightly different from the circuit of Fig. 3. There is no diode, the grid-cathode portion of VT-1 being used as a diode, and there is no battery B_1. Only a small fraction of the oscillating voltage is transmitted to the grid of VT-2 by means of the potentiometer divider C_1C_2. The sensitivity is much smaller than the circuit of Fig. 3, but is still sufficient to give a perfect stabilization. Tube VT-3 is used also as an electronic voltmeter, and the oscillating voltage across C_2 is indicated on the meter M.

Adjustment for the best control is easy. The bias of the cathode of valve VT-3 should be adjusted until maximum stabilization is obtained. If the cathode should be given a positive potential greater than the maximum oscillating peak voltage, there will be no control at all as the tube will always have an infinite impedance. By making the cathode progressively more negative, the control increases until some point is reached at which the load on the tuned circuit, at the peaks, becomes so great that the control is maximum and the amplitude of the oscillating voltage start to decrease rapidly. The best operating point will be just before this occurs. With the circuit as described and as adjusted in the man-



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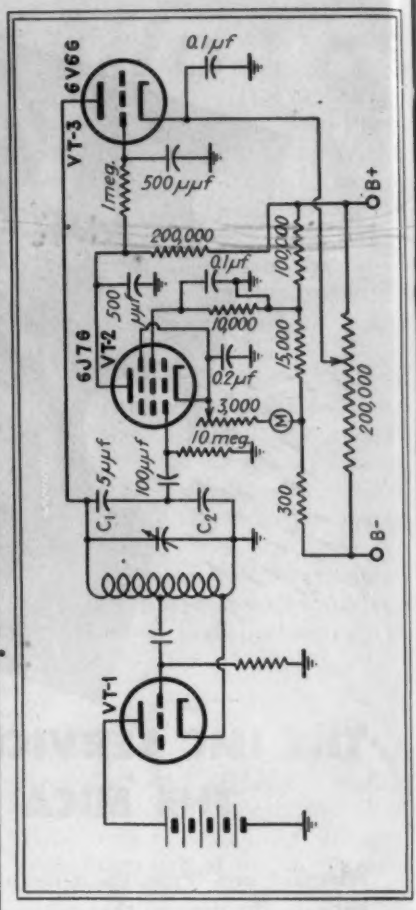

Fig. 4—Practical circuit used to hold output voltage constant on a multirange oscillator covering frequencies from 30 kc to 9 Mc. One grid and the cathode of VT-2 form the detector

ner just explained, it is possible to maintain the oscillating voltage constant within about one percent when it would vary by perhaps 200 percent without any control.

The circuit of Fig. 4 has been tried with five different coils in order to cover the frequency band from 30 kc to 9 Mc, and for each coil the stabilization was found perfect.

Although the control circuit employs three tubes, the total power necessary for operating them can actually be made small compared with the power necessary for the oscillator. For example, VT-2 could

—◇—

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be a very low-power tube whose maximum current is not more than, say, 2 milliamperes; and tube VT-3, owing to the manner in which it operates, will generally draw a plate current of less than 1 ma, even if a power tube such as a 6V6 or 6L6 is used. The voltage divider arrangement can also be arranged so that the total current drain is not more than about 7 ma.

• • •

Electronics in AIEE

MORE PAPERS on electronic subjects were presented at the summer technical meeting of AIEE in St. Louis during June than have been given at meetings in the past. Among those with electronic significance, one by N. D. Kenney and Perry H. Ware referred to design and testing of coaxial cables.

The first part of the paper presented a discussion of the variation of transmission line parameters, both basic and working, as a function of construction and frequency. True and approximate formulas were given for computing cable properties, with notes on applicability and limitations as well as practical methods of test.

Simplification of the analytical expressions for rectifier behavior was the objective of a paper by E. F. Christensen and C. C. Herskind of General Electric and C. H. Willis of Princeton University. The paper gives the methods used in analyzing rectifier circuits, illustrates the application of new circuit concepts, provides standard procedure for analysis of rectifier circuits, gives a standard form for the presentation of rectifier characteristics, and presents a comprehensive set of characteristic curves for the delta double-y rectifier.

Design and tests of a mercury-vapor rectifier with exciter anodes was summarized by H. Winograd of Allis-Chalmers Mfg. Co. He described the application to electrochemical service of a 12-tank Excitron unit rated at 5,000 amp., 650 volts d.c.

Control for Welding

Improved electronic control for capacitor-discharge resistance welding was presented by H. J. Bichsel and E. T. Hughes of Westinghouse. This paper describes a capacitor-

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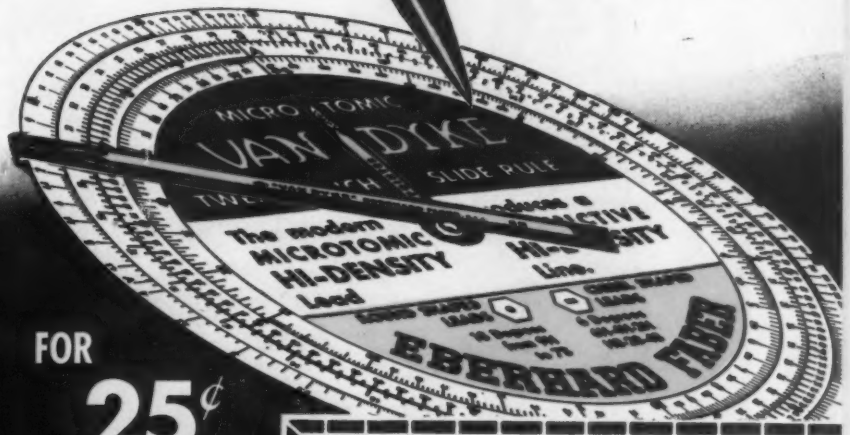

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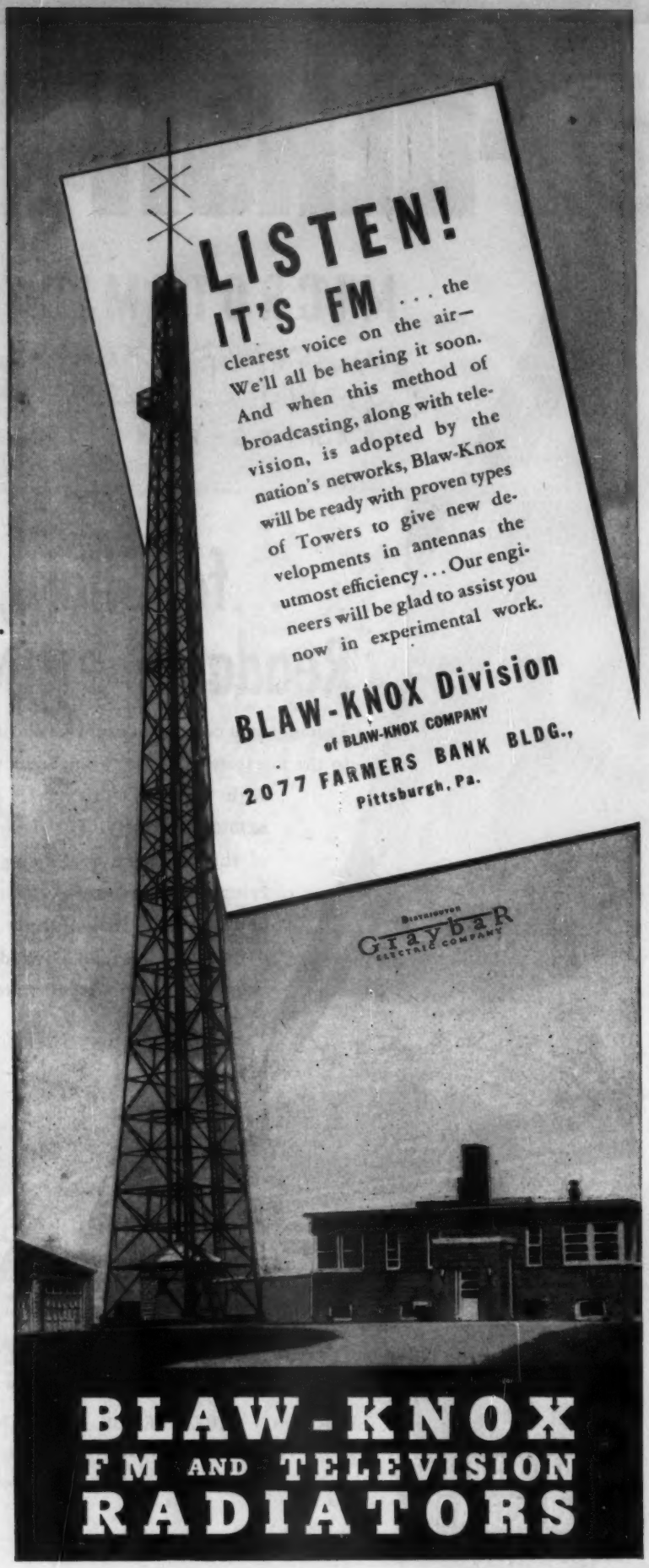
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Fundamentals of hearing-aid design were covered by W. D. Penn. He showed that frequency-selective amplification is usually beneficial and described a method of obtaining this type of action, with mathematical analysis to support the conclusion. Means of computing acoustical amplification were also described.

By combining the advantages of electronic tubes and symmetrical component filters, a new carrier relay results in a marked simplification over previous systems. It was described by T. R. Halman and A. F. Drompp of Detroit Edison Co. and S. L. Goldsboro and H. W. Lensner of Westinghouse. Not only has the number of relays been reduced but the number of operating elements per relay as well.

In an aircraft engine torque meter described by F. W. Godsey, Jr. and C. F. Langer of Westinghouse, resistance straingage elements and vacuum tube amplifiers are combined. The paper included an extensive survey of methods for measuring torque.

Electronic Frequency Conversion

In a symposium devoted to the subject of electronic power conversion, one paper referred to the installation of a 20,000-kw electronic converter to exchange power between 25 and 60 cycles. The converter was described by F. W. Cramer of Carnegie-Illinois Steel Corp. and L. W. Morton and A. G. Darling of GE.

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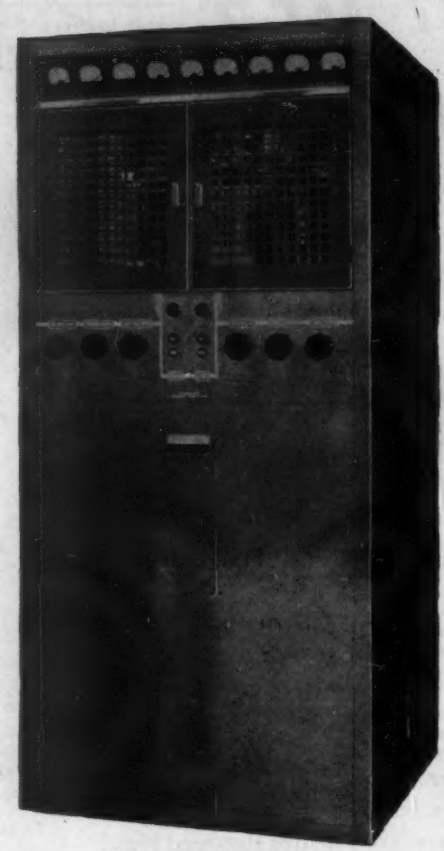

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fying elements under conditions of unbalance were considered by E. F. Christensen and M. M. Morack of GE. Effects of such unbalances on circuit duty and rectifier capacity were indicated.

Measurement of dielectric properties at uhf by the resonant cavity method was considered by C. N. Works, T. W. Dakin, and F. G. Boggs of Westinghouse. In this method a reentrant cylindrical cavity is adapted to measure the dielectric constant and power factor of small disks, samples, and insulating material. Methods of measurements, mechanical details, and electric coupling and detecting circuits employ technique common to uhf. Because the cavity has a value of Q higher than 2,000, it is much more sensitive to low power-factors of samples than any conventional coil- and capacitor-resonant circuit.

Furnace Regulation

Electronic motor control for regulating arc furnaces was covered in a paper by J. E. Reilly and C. E. Valentine of Westinghouse. The method has proved successful on many applications where a wide range of speed control and quick response are desired. Many combinations of acceleration and speed range can be obtained with a minimum of apparatus and almost instantaneous response. In the electronic system, the field is held constant and the armature voltage is varied to give the desired speed. Moving parts are eliminated from gear ahead of the motor.

• • •

D-F IN FCC CAR

A mobile direction finder used by the FCC to trace outlaw stations is explained to Congressmen Hart and Wigglesworth by J. B. Lewis (right), monitoring officer in charge of the mobile unit

HOW ELECTRONIC HEAT INCREASED SPAR OUTPUT 700%

Here's How Tolerton Lumber Co. Met Increased Production Demands

BEFORE December, 1941, wood aircraft manufacturers were using spars cut from solid wood planks. But the supply of Grade A spruce for such spars was also limited. Thus spars laminated from thin pieces came into the picture; next, to further conserve lumber, short lengths were scarf-jointed; and finally narrow widths had to be edge-glued in order to meet demands.

As a result of these many operations, costs and production time increased sharply.

The Tolerton Lumber Company, applying electronic heating to speed the setting of the glue, found that edge-glued joints could be "set" in 2 minutes; that 8 scarf joints could be "set" simultaneously—in about 10 minutes; and that a 6" x 6" x 16½' beam could be laminated from several planks in about 20 minutes by electronic heat (former time in hot-platen press was 4 hours).

The aircraft spars are cut from these 16½ foot beams.

Tolerton uses an RCA 15-kw electronic generator.

Results:

1. Because electronic heating shortened press time so greatly, the Tolerton plant output was increased from 25 spars per day to 200!

2. The setting of the glue is complete because electronic heating produces uniform temperature throughout the glue line.

3. Lumber costs were cut about 40% by using odd pieces!

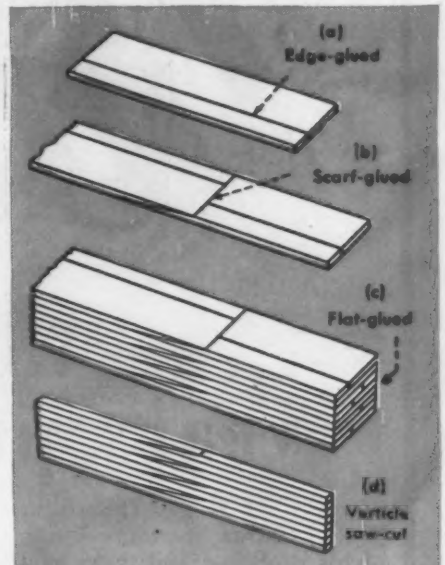
4. In tests of these glue joints, wood failure runs 100%—considerably above the 80% acceptable under Government specifications.

For more complete information on this application, send the coupon below.

Other Applications by Tolerton: "In addition to manufacturing spars and other aircraft parts such as ailerons, fairings, fins, capstrips, etc., at a big saving in time, lumber, and expense," wrote Mr. R. I. Tolerton, vice-president of the Tolerton Company, "we are also using this electronic method of gluing in the manufacture of lithograph backing blocks and steelmill hammer boards.

"The manufacturing rate has increased greatly, and the products are more accurately made because of the added glue adhesion obtained by electronic heat. We also laminate 6-inch square maple blocks which are later turned to make wheel-bearings for bombers. Electronic heat has made these blocks the most satisfactory material yet found for the purpose."

Want More Details? The complete story of the Tolerton operation—together with pictures, drawings, diagrams, and curves—is contained in a free 8-page article "Electronic Heating Sets Glue in Laminated Aircraft Spars." Write for it, or send the convenient coupon. If you have a problem electronic heating might solve, write us the details; our engineers may be able to help you. Address Radio Corporation of America, Electronic Apparatus Section, (70-40H), Camden, N. J.



Steps in the construction of the spars: (a) edge-gluing to obtain 6-inch width, (b) scarf-gluing to obtain 16½-foot length, (c) laminating to obtain 6-inch by 6-inch by 16½-foot beam, (d) beam cut to obtain edge-grain laminated spars ¾ inch by 6 inches by 16½ feet.

RCA 15-B Electronic Power Generator which supplies about 50,000 B.T.U. per hour. (Send coupon for bulletin.)

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Special new low frequency unit . . . vital in the newer fields of electronics.

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Remote Amplifier

(*Continued from page* 131)

visible indication of field intensity in the null point of the radiation pattern. In contrast to a method in which a reading must be taken periodically by a comparison or balancing method, this continuous indication will give immediate warning of an increase in the signal in the unwanted direction, and could of course be readily adapted to operate a relay sounding an alarm.

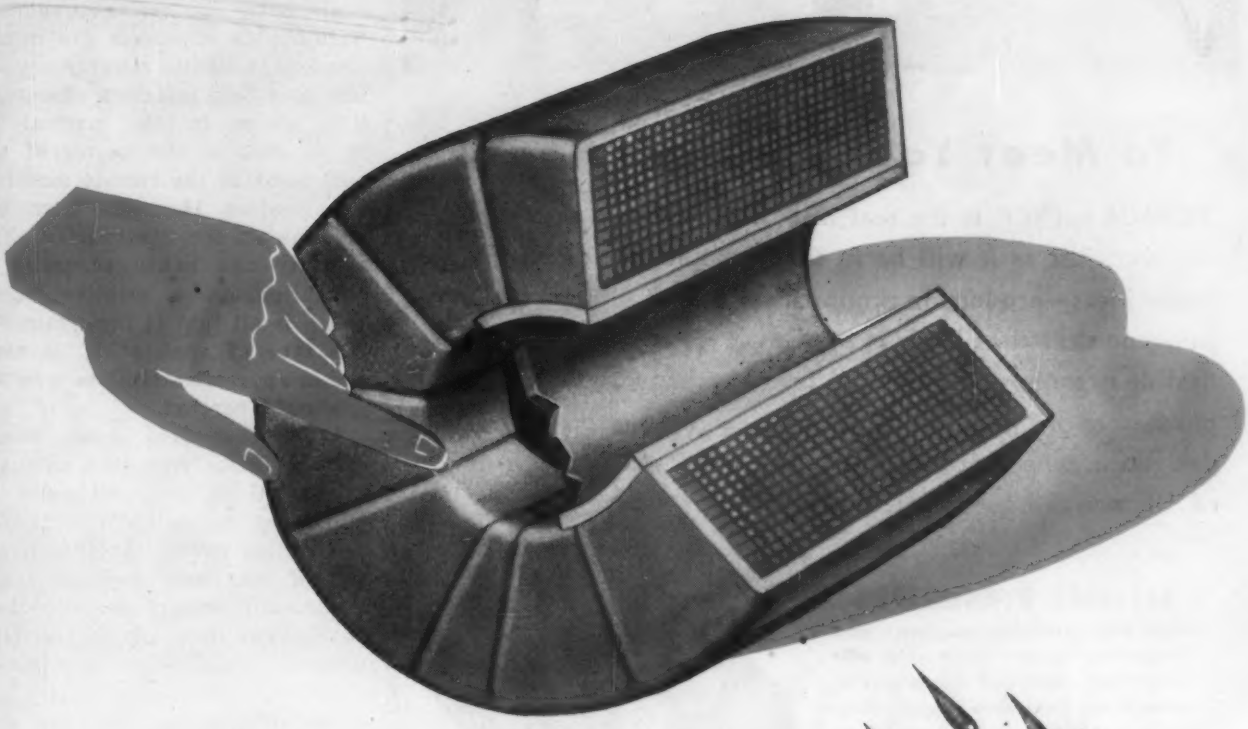
Regulation of Voltages

Development of the remote monitor system involved dealing with several variables which affected its indications. Voltage variations were taken care of by a regulator in the line, and by gas-tube voltage-regulators in the receiver high-voltage supply.

Fluctuations in the receiver itself caused most of the trouble encountered. These were found to be due to frequency drift of the local oscillator of the superheterodyne type receiver originally used, which caused it to become detuned sufficiently to reduce the detector current. Attempts to deal with this particular variation by means of temperature-compensating capacitors were less successful than the adoption of a t-r-f type receiver such as the one shown schematically.

Extreme changes in ambient temperature occur in the semi-desert valley location of the transmitter. Because of the d-c indication method used, changes in resistance of the telephone line were anticipated as a factor which might have to be dealt with. On a typical hot summer day, temperature ranges from 64 to 102 deg F, between 4 a.m. and 4 p.m. Measurements of the resistance of the line, totaling as a loop 11,485 ft, showed a change with this temperature range of about 14 ohms in the total resistance of 413 ohms at the low temperature point. This variation in line resistance is sufficient to cause only a barely noticeable change in the reading of the microammeter. The system is otherwise stable enough

Anaconda Wrapseal Coils



especially designed to resist moisture

Wrapseal construction, developed a number of years ago by Anaconda coil engineers, has proved highly acceptable where cost is a factor and, at the same time, good moisture-proof properties are essential.

The winding usually consists of a standard paper section coil, varnished where desired. The balance of the construction is markedly different from ordinary practice.

The entire outer surface of the coil is encased in one piece of insulation which not only completely covers the coil, *but extends into the core of the coil between the winding and the core tube.*

After this wrapseal is applied, the entire coil is treated with a thick coating of special varnish.

These coils are excellent for applications where considerable moisture is present—for example, in solenoid operated water valves, in laundry equipment, etc. Additional information may be obtained from any of our sales offices.

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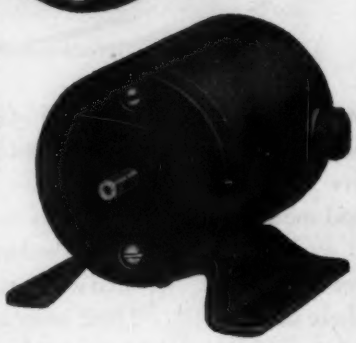
ALLIANCE D. C. MOTORS

Incorporate precision tolerances throughout. Light weight—high efficiency—compactness. An achievement in small size and in power-to-weight ratio. Careful attention has been given to distribution of losses as well as their reduction to a minimum.



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to permit this deviation to be observed on a hot day.

Accuracy of the System

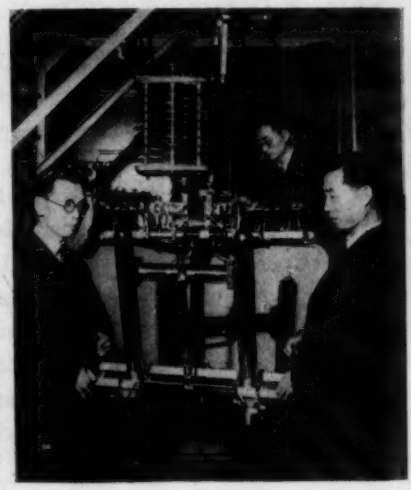
The 6H6 rectifier current which goes over the telephone line is about 220 microamperes, and is read on a 500-microampere full-scale meter. This current remains within plus or minus five microamperes, which is roughly equivalent to a field intensity change of 0.75 mv/m in the normal 31 mv/m area at the center of the null point at the remote monitoring location 1½ miles from the antenna of the transmitter. The stability and hence accuracy of indication on a relative basis, which is all that is important for this type of application, is thus within approximately 1 part in 30, or about 3 percent.

At another field measurement point 4½ miles from the antenna, the signal in the null point is equivalent to only 28 watts of transmitter power. In the direction of maximum radiation, approximately southward over Los Angeles and its environs, the field intensity is equivalent to a power of 38 kw.

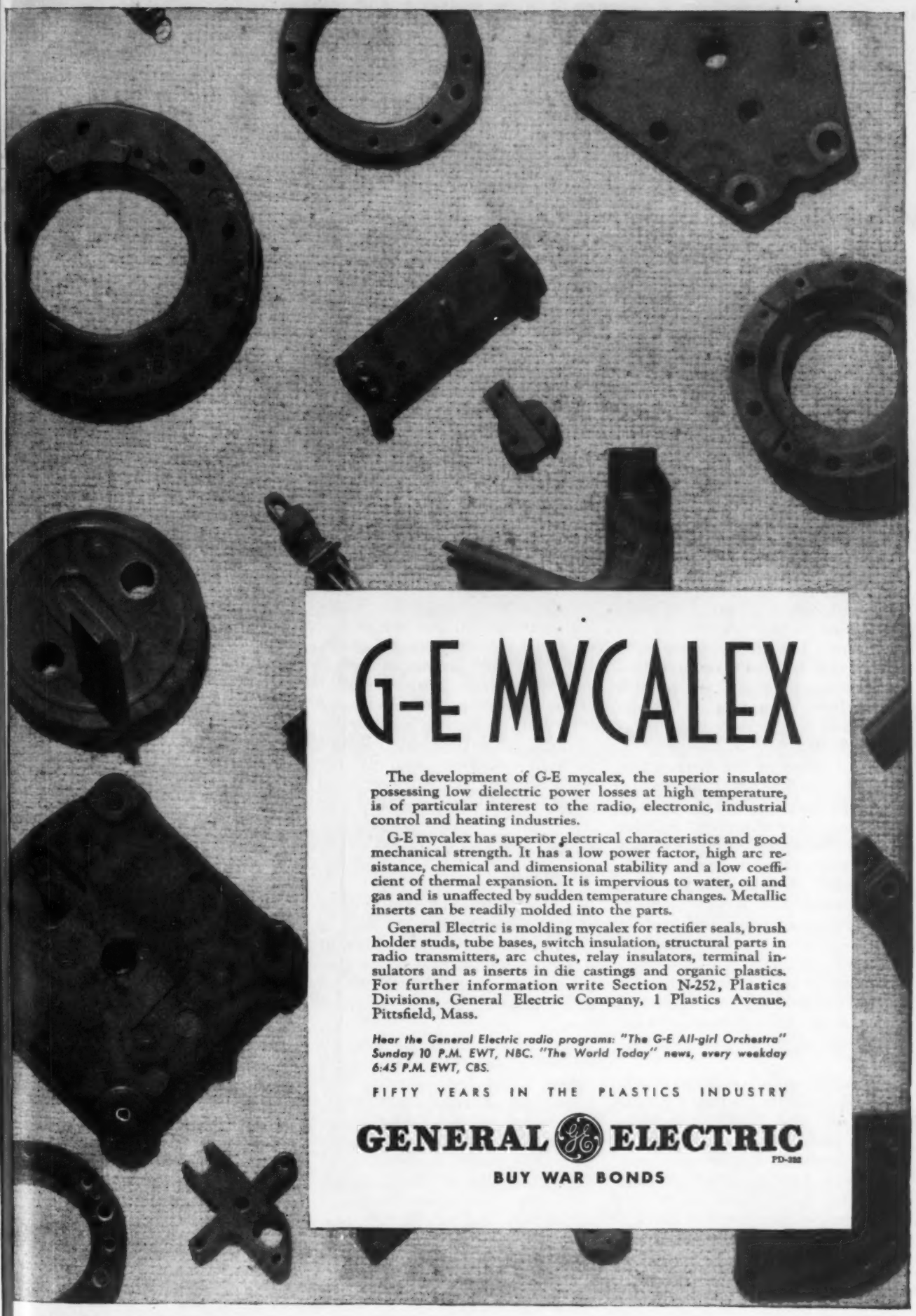
This remote monitor was devised by Major Lloyd C. Sigmon, formerly chief engineer of KMPC, who also installed the transmitter and directional antenna system.

• • •

ELECTRONICS FOR CHINA



Two Chinese engineers remove the anode coil from a high-power broadcast transmitter made in England for China, while the third examines a band-change unit mounted on a turntable. Young Chinese are being trained in Britain for postwar reconstruction in their own country



G-E MYCALEX

The development of G-E mycalex, the superior insulator possessing low dielectric power losses at high temperature, is of particular interest to the radio, electronic, industrial control and heating industries.

G-E mycalex has superior electrical characteristics and good mechanical strength. It has a low power factor, high arc resistance, chemical and dimensional stability and a low coefficient of thermal expansion. It is impervious to water, oil and gas and is unaffected by sudden temperature changes. Metallic inserts can be readily molded into the parts.

General Electric is molding mycalex for rectifier seals, brush holder studs, tube bases, switch insulation, structural parts in radio transmitters, arc chutes, relay insulators, terminal insulators and as inserts in die castings and organic plastics. For further information write Section N-252, Plastics Divisions, General Electric Company, 1 Plastics Avenue, Pittsfield, Mass.

Hear the General Electric radio programs: "The G-E All-girl Orchestra" Sunday 10 P.M. EWT, NBC. "The World Today" news, every weekday 6:45 P.M. EWT, CBS.

FIFTY YEARS IN THE PLASTICS INDUSTRY

GENERAL ELECTRIC

PD-282

BUY WAR BONDS

NEWS OF THE INDUSTRY

Conventions to come; Canadian radio; Electronic Conference program; D. C. Bias, words from Washington; television and electronic instruction; transmission facilities; military communications

Radio on Maneuvers with the Airborne Artillery

THROWING OUT RADIOS and other equipment to float down on color-coded parachutes, 500 men of the 541st Parachute Infantry Regiment and the 467th Parachute Field Artillery Battalion dropped near Camp MacArthur, Long Island, recently to show visiting Army and Navy dignitaries and reporters how an air strip is captured by airborne forces.

From bomb-racks on the C-47 transports which brought the paratroopers in, so-called daisy chains of 75-mm pack howitzer parts were released. Each demountable piece of the gun is provided with its own parachute but all the parts of a single gun are tied together with a long streamer of cord which keeps them from separating on the descent and facilitates finding the individual bundles on the ground. Colored lights on the bundles also aid in detection and identification of dropped equipment after dark.

Each battery of artillery includes four transmitter-receivers, each with two standard channels, crystal-controlled. Channel A is the basic use channel with B as a standby. Battery commanders are kept in touch with battalion command through a separate radio net which is tuned to a K channel. Besides the crystals in the transceivers, a large supply of additional units are carried along for frequency change-over.

In actual combat, one-man sets in the 300 series are used but for these exercises, type BC-659-A combinations made by Galvin Mfg. Corp., were dropped. Requiring a two-man team, they consist of radio and batteries in separate containers which are coupled together mechanically with trunk-type hasps and electrically with plugs and cables. The telescopic antenna is demountable and carried in clips on top of the radio cabinet.

Although normal communication is carried on with a push-to-talk, hand-held microphone and a speaker in the panel, provisions exist for earphones at points close to enemy lines where silence must be maintained. For use at a forward observation post where the operator wishes to conceal the antenna mast by placing the set on lower ground, microphone and earphone extensions permit remote operation.

Equipment bundles include form-fitting protective pads of mattress-like construction, but one zealous crew had borrowed the sofa cushions from their day room for extra security against damage. In spite of the standard precautions, one of the units suffered considerable physical distortion but operated perfectly. Another, with no outward sign of injury, went dead after a few minutes of use.

Book of Electronic Standards

IN A BOUND COMPILATION of results of the standardization program in WPB's radio and radar division, 21 American war standards for electronic components are brought together in a single, convenient reference.

Because the standards were developed in cooperation between the armed forces and industry, they satisfy the extremely critical requirements of the armed forces without going beyond the capabilities of industry regarding large scale production. Thus it is anticipated that besides constituting a sound basis for war standardization, they may also serve as a nucleus for postwar development.

Contents include ceramic insulating materials, fixed mica-dielectric capacitors, meter resistors, glass-bonded mica insulators, fixed composition resistors, glass insulators, wire-wound resistors, crystal units, fixed ceramic-dielectric capacitors, dynamotors, porcelain radio insulators, toggle switches, fixed paper-dielectric capacitors, method of noise-testing fixed composition resistors, electrical indicating instruments, shock-testing mechanism for indicating instruments, external r-f thermocouple converters, external ammeter shunts, and fixed molded paper-dielectric capacitors.

Search for Scientists

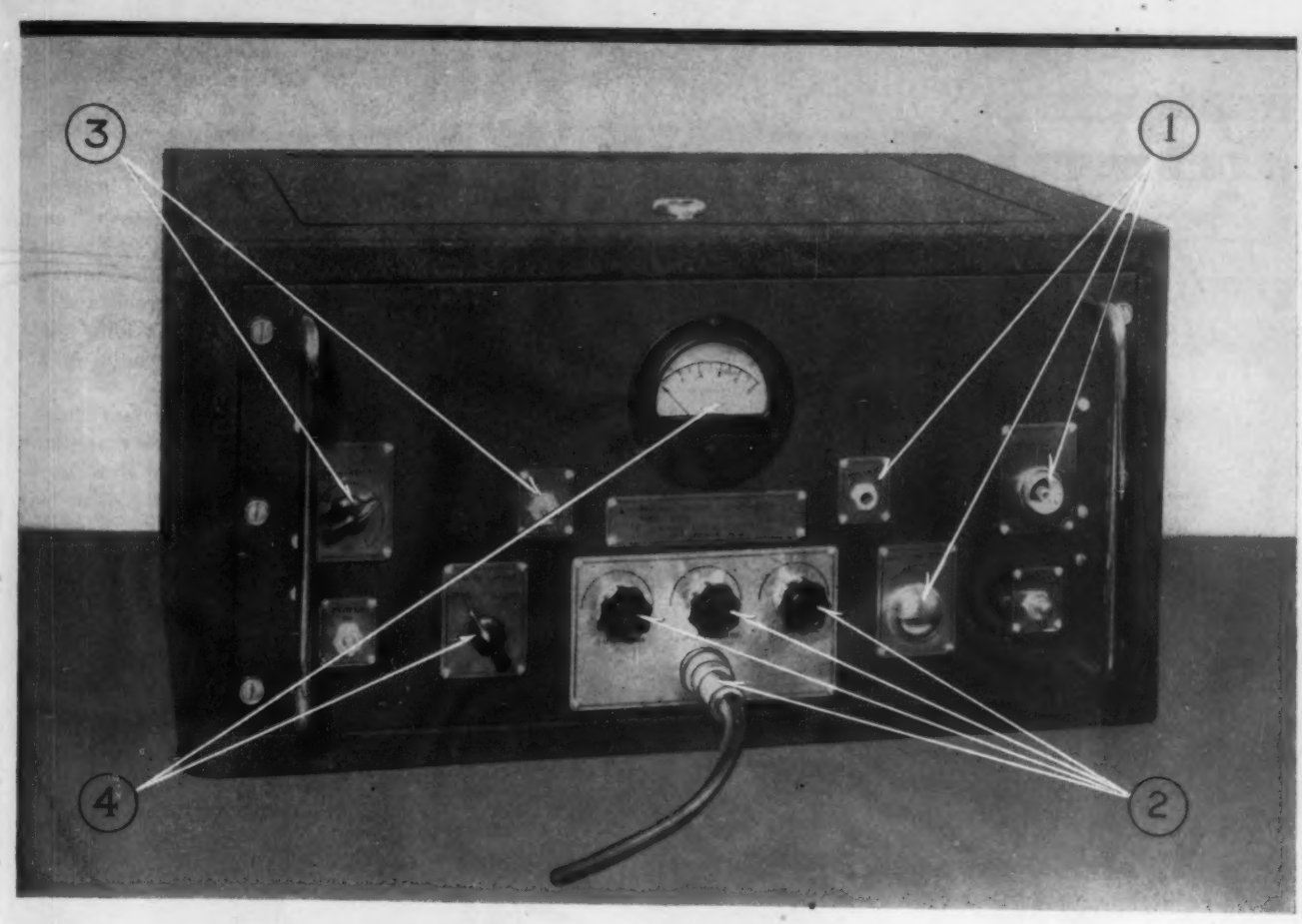
REQUESTS FROM INDUSTRIAL and government laboratories, for research personnel; from colleges, for teachers; and from industrial establishments, for miscellaneous scientifically trained persons, are reaching the office of scientific personnel of the National Research Council in large numbers. The supply of able scientists has never seemed so small in relation to the demand.

One of the functions of this office is to assist in the recruitment of scientists for positions in war-supporting activities. Since it is in touch with demands from all types of activities, it is in a position to refer an able scientist to employers engaged in urgent work. Demand is particularly heavy for people trained in electronic and communication engineering, in physics, and in mathematics. Individuals who are or may become available should write to Dr. M. H. Trytten, director, 2101 Constitution Ave., Washington 25, D. C.

Convention Coverage by Television

SCENES FROM the recent Chicago conventions were put on the air from film within 18 hours of their actual happening. Television set owners in 5,000 homes in New York, Philadelphia, and Schenectady were able to see important interviews and actual deliberations on the convention floor through television network facilities. Films for exclusive television use have never before been produced on so extensive a scale.

Production at the Stadium in Chi-



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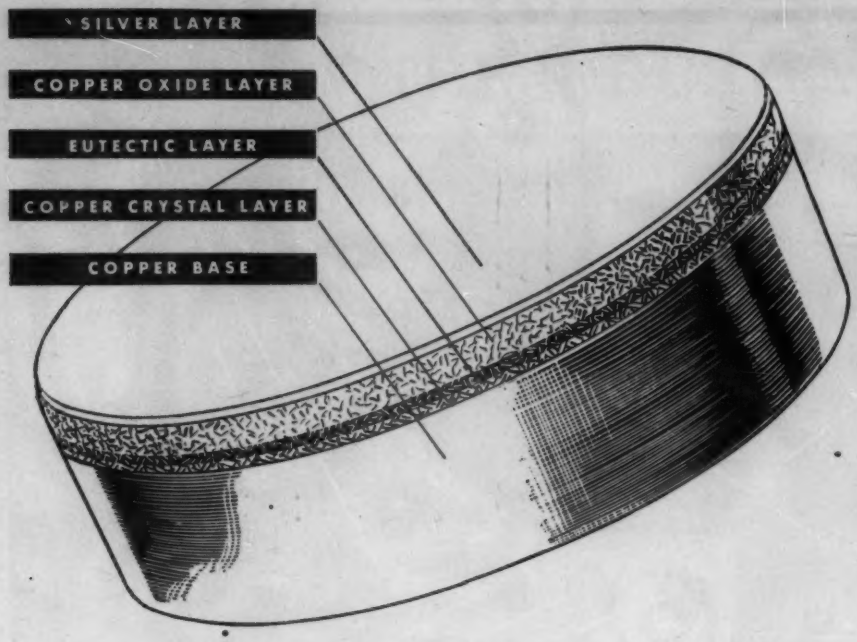

CONANT RECTIFIERS
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In the manufacture of Conant rectifiers, the layer of copper oxide is formed in the usual manner but it is then caused to alloy with the underlying copper to form a copper-copper oxide eutectic. Then by careful control of timing and temperatures, the eutectic alloy is caused to crystallize in a form resulting in a very stable asymmetric junction especially suited for instrument applications. The molecular structure of the junction so formed required the development of new and unusual processing methods.

Every step in the Conant process has been correctly developed. From the precision lapping of the discs, through the application of the contacting layers and chemical treatments, to the final assembly, each careful operation assures a rectifier assembly that will give the utmost satisfaction in instrument service.

Yes, Conant rectifiers *are* different, because of the *extra* care and the *plus* precision that go into their manufacture. Their enviable record of service is the proof.

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cago was handled by Pathe News. Due to differences in television technique, it was necessary to instruct the veterans newsreel cameramen to make certain changes in their normal procedure. For one thing, far greater footage of each scene was required. Also, because of the small size of the television screen, a greater percentage of closeups was used, with long shots serving only for background or atmosphere.

The shooting supervisor maintained a schedule of every airplane flight from Chicago for New York. As each zero hour neared, film was unloaded from the camera magazines, labelled, and rushed to the plane with police escort. At New York, the films were rushed to the laboratory and developed. National Broadcasting Company, from whose WNBT the presentation originated, televises negative instead of positive film. This saved considerable time in finishing and made it possible to edit the reels quickly.

CONVENTIONS TO COME

Sept. 11. Symposium on Fluorescence and Luminescence, New York, N. Y. **American Chemical Society,** James T. Grady, 609 Journalism Bldg., Columbia University, New York 27, N. Y.

Sept. 11–16. **American Association for the Advancement of Science,** Cleveland, Ohio. F. R. Moulton, secretary, Smithsonian Institution Bldg., Washington 25, D. C.

Sept. 14. Regular Meeting, New York, N. Y. **Radio Club of America,** Milton B. Sleeper, corresponding secretary, 11 West 42 St., New York 18, N. Y.

Sept. 18–20. Eleventh Annual National Conference, Toledo, Ohio. **Associated Police Communication Officers, Sgt. C. H. Knudel,** chairman, 720 Jefferson Ave., Toledo 2, Ohio.

Oct. 2–5. Forty-Ninth Annual meeting, Boston, Mass. **International Municipal Signal Association,** Irwin Shulsinger, secretary, 8 East 41 St., New York, N. Y.

Oct. 5–7. **National Electronics Conference,** Chicago, Ill. B. Dudley, secretary, 520 N. Michigan Ave., Chicago, Ill.

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REMLER ENGINEERS design and build robots with "brains" to improve production techniques. Ingenious jigs and dies, and in many instances entire machines are constructed to combine intricate operations. These innovations contribute to the precision accuracy of Remler products; release manpower for other tasks; reduce costs and speed up deliveries. • For complete sound transmitting systems; radio; plugs and connectors and other electronic components in metal and plastic, consult . . .

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50-A	61	74	114	150	
54	62	76	119	159	
55	63	77	120	160	1136-1
56	64	104	124	291-A	
58	65	108	125	354	No.
59	67	109	127		212938-1
60	68	112	149		

PLP		PLQ		PLS	
56	65	56	65	56	64
59	67	59	67	59	65
60	74	60	74	60	74
61	76	61	76	61	76
62	77	62	77	62	77
63	104	63	104	63	104
64		64			

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FRACTIONAL H.P. MOTOR

For use in model work, or in any usage where a small, powerful, slow speed motor is required. Compact, 1/20th horsepower induction type. Operates from 25 to 30 volts AC, 60 cycles. Motor speed 2400 RPM, with gear train driving ¼" shaft at 24 RPM. 2" x 1¾" x 3" overall, excluding shaft.

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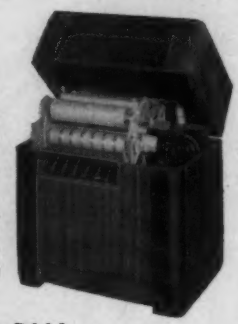
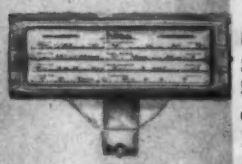
RCA FACSIMILE BROADCAST RECEIVER

RCA MODEL FAX-2A



Fully automatic pre-tuned high fidelity radio receiver, facsimile printer amplifier, facsimile printing unit, and Telechron time switch clock. This instrument has many uses in the laboratory. The printing unit utilizes carbon paper in contact with white paper as a recording medium. Complete with tubes and operating and service instructions, but less recording paper.

M25749 ..... $99.50



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Single speed vernier dial mechanism. Fits ⅜" shaft. 5-band scale calibrated 5.85-18.2 mc and 17.6-42mc. Includes escutcheon and bayonet type dial-light sockets. Ratio 17:1.

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2-section unit. 1375 ohms each section. Each covering approximately 40 degrees rotation, and insulated from each other. ¼" shaft.

M8168 ..... $1.39

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5-inch. For call systems, hearing aids and midget radios.

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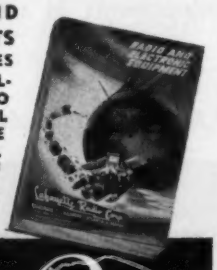

Lafayette Radio Corp.

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Oct. 12–14. Fall Meeting, Buffalo, N. Y. **Electrochemical Society,** Colin G. Fink, secretary, Columbia University, New York 27, N. Y.

Oct. 16–18. Fifty-Sixth Semi-Annual Fall Conference, New York, N. Y, **Society of Motion Picture Engineers,** W. C. Kunzmann, vice president, Hotel Pennsylvania, New York, N. Y.

Oct. 16–19. Twenty-Fifth Annual Meeting, Cleveland, Ohio. **American Welding Society,** M. M. Kelly, secretary, 33 West 39 St., New York 18, N. Y.

Oct. 19–21. Electronic Parts and Equipment Industry Conference, Chicago, Ill. **Association of Electronic Parts and Equipment Manufacturers; Eastern Div., Sales Managers Club;** and **National Electronics Distributors Association.** H. W. Clough, chairman, PO Box 5070-A, Chicago 80, Ill.

Nov. 2–3. National Time and Motion Study Clinic Chicago, Ill. **Industrial Management Society.** C. S. Becker, vice president, 205 West Wacker Drive, Chicago 6, Ill.

Nov. 13–14. Annual Receiver- and Tube-design Meeting, Rochester, N. Y. **Radio Manufacturers Association** and **Institute of Radio Engineers;** Bond Geddes, secretary RMA, 1317 F St. N.W., Washington, D. C.; Haraden Pratt, secretary IRE, 330 West 42 St., New York 18, N. Y.

Nov. 9–10. Fall Meeting, Dayton, Ohio. **Institute of the Aeronautical Sciences,** Robert R. Dexter, secretary, 1505 RCA Bldg. West, Rockefeller Center, New York 20, N. Y.

Naval Electronic Production

DELIVERIES OF RADIO and other electronic equipment for the Navy are currently reported to be well in excess of $100,000,000 monthly. This figure is five times the total production for all purposes in 1940.

Electronic Conference Program

SCIENTIFIC DEVELOPMENTS in electronics and electronic applications in industry and medicine are to be emphasized at the National Elec-

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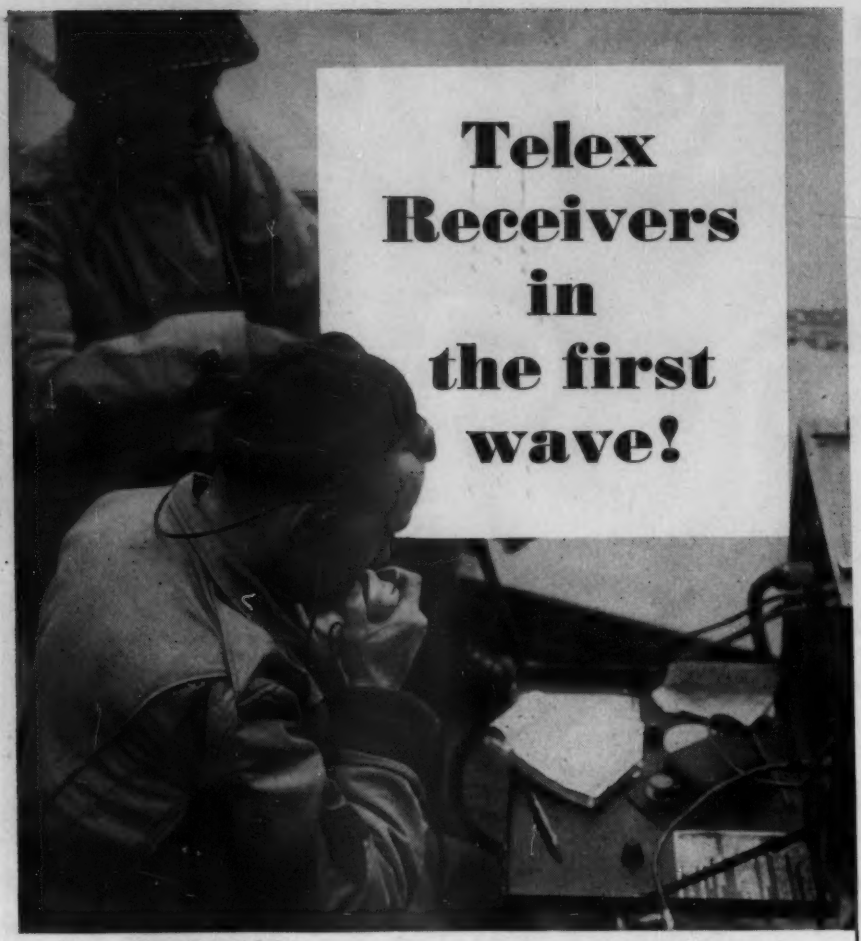


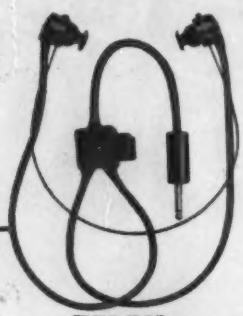
Photograph Signal Corps, U. S. Army

Telex in the Aleutians

Yes! Telex Receivers played a vital part in 1943 during the occupation of Attu Island in the Aleutians. When this picture was taken the first wave of occupation forces were just landing on the rocky beaches of Attu Island.

Telex magnetic receivers bring each vital message with crystal clearness to the anxious ears of the radio operator. Tireless preparation by Telex engineers guarantees our boys dependability—the best that American engineering can produce.

The prolonged hours of careful research and analysis which the engineers of Telex have devoted in creating the first wearable Electronic Hearing Aid and in serving the U. S. Army Signal Corps should be valuable in helping you solve your electronic development problems. Write us today.



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EXPERIENCE OFFERS

Magnetic Receivers:

Cu. Vol.—Approx. 0.3 cu. in.

Impedance—Up to 5000 ohms.

Sensitivity—18 dynes/sq. cm. for 10 microwatt input.

Construction—Rugged and stable, using only finest materials, precisely machined—no diaphragm spacing washers in Telex receivers.

Transformers and Chokes:

Cu. Vol.—Down to .15 cu. in.

Core Material—High permeability steel alloys.

Windings—To your specs. (Limit of six outside leads on smallest cores.)

ELECTRONIC PRODUCTS DIVISION

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tronics Conference in Chicago, October 5 to 7. The program has been prepared by Professor Arthur B. Bronwell of Northwestern University and a tentative list of subjects is classified as follows.

Television

Color and U-H-F Television by Dr. P. C. Goldmark, CBS.

Reflective Optics in Television by I. G. Maloff and D. W. Epstein, RCA.

Radio Relay Systems by C. W. Hansell, RCA Labs.

Ultrahigh Frequencies

A Lighthouse Tube; a Pioneer Development by E. F. Peterson and E. D. McArthur, G. E.

Principles of Klystron Amplifiers by Dr. Robert Haxby, Sperry.

Developments of Electronic Tubes by I. E. Mourontseff, Westinghouse.

Wide-Frequency-Range Tuned Circuits for High Frequencies by Dr. D. B. Sinclair, General Radio Co.

U-H-F Converters and Conversion Diagrams by Dr. Harry Stockman, Harvard.

Radio

Generation of Quasi-Continuous Frequency Spectra by Dr. Harold Goldberg and Richard G. Talpey, Stromberg-Carlson.

A Frequency-Dividing Lock-In-Oscillator F-M Receiver by G. L. Beers, RCA.

Incremental Premeability Tuning by W. J. Polydoroff, Consulting Engineer.

Audible Audio Distortion by H. H. Scott, General Radio Co.

Broadband Carrier and Coaxial Cable Networks by P. A. Cowan, AT&T.

Industrial Measurements and Special Devices

Supersonic Reflectoscope for Inspecting the Interior of Metal Parts by Dr. F. A. Firestone, University of Michigan.

Dynamic Strain Gages by C. A. Dohrenwend, Armour Research Foundation.

The Mass Spectrometer and Its Practical Applications by J. A. Hipple, Westinghouse.

Two-Million-Volt X-Ray Unit by Dr. E. E. Charlton and W. F. Westendorp, G. E.

Industrial Fluoroscopy of Light Materials by Dr. Scott W. Smith, Kelley-Koett Mfg.

Application of Amplifier Theory to Mechanical Stability Problems by John M. Cage, Allis-Chalmers.

Industrial Electronic Controls

Electronic Mechanisms in Process Plants and Industrial Laboratory by T. A. Cohen, Wheelco Instrument Co.

Electronic Measurements of Non-Electrical Quantities by H. D. Middell, G. E.

Cathode Ray Tubes and Their Application by Dr. P. S. Christaldi, Allen B. DuMont Laboratories.

Electronics in Instrumentation by Walter P. Wills, Brown Instrument Co.

Design Factors in the Application of Relays by R. H. Herrick, Automatic Electric Co.

Induction Heating

High Frequency Induction Heating by C. J. Madsen and R. M. Baker, Westinghouse.

New Methods and Techniques in High Frequency Heating by Dr. Eugene Mittelmann, Illinois Tool Works.

High Frequency Electronic Generators for Industrial Heating by Dr. Wesley Roberds, RCA.

Electronic Applications in the Power Field

Power Applications of Electronics by A. C. Montieth, Westinghouse.

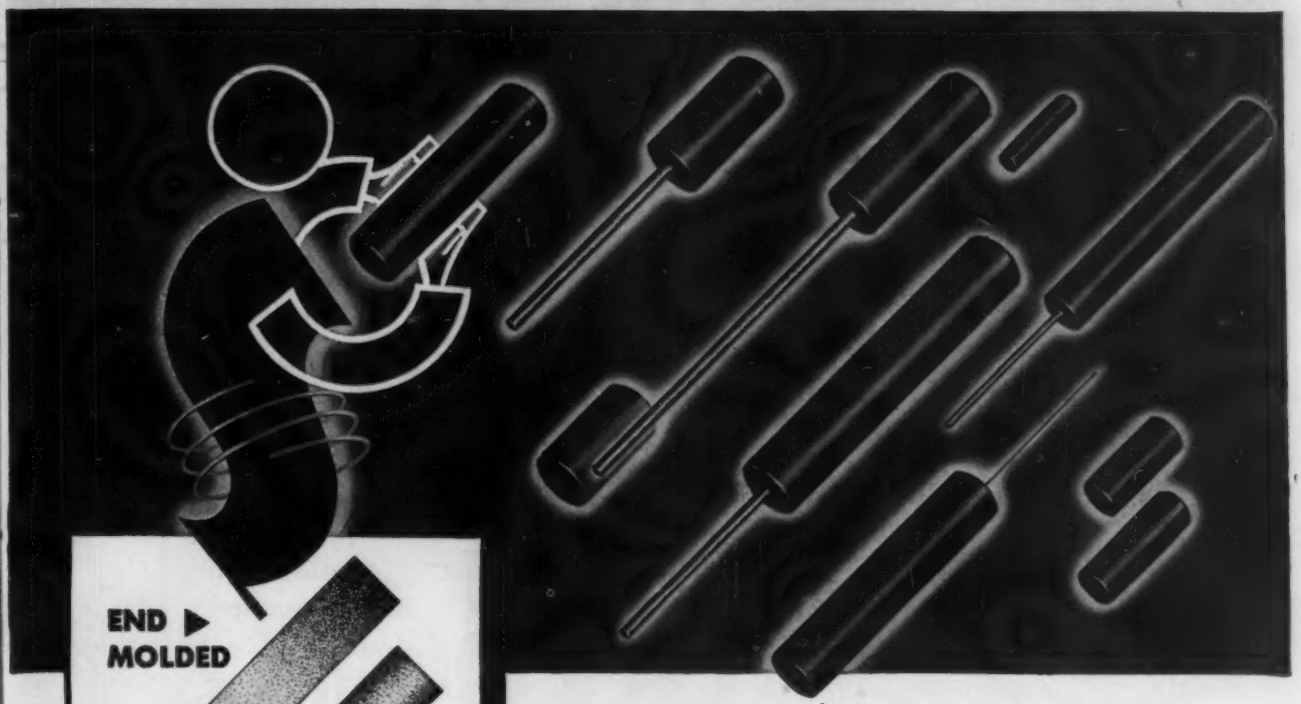
Power Rectifiers and Inverters by J. A. Cox and G. F. Jones, Westinghouse.

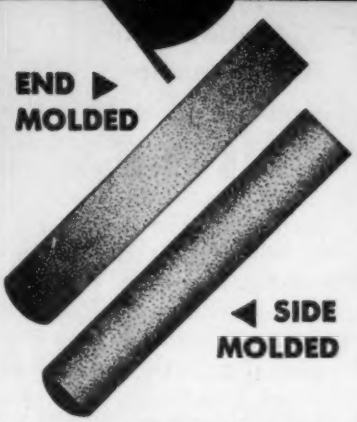
Electronic Power Converters by Dr. E. F. W. Alexanderson, G. E.

Medical Applications of Electronics

Electronic Equipment in the Medical

SIDE-MOLDED IRON CORES





This diagrammatic illustration shows how conventional cores, molded by applying pressure to the ends, results in a dense grouping of iron particles at these points. In side-molded cores, however, any density resulting from molding pressure extends evenly along the entire length of the core, assuring uniform permeability with respect to length.

Uniform Permeability with Respect to Linearity

Use in many applications has shown Stackpole side-molded iron cores outstandingly superior to conventional end-molded cores for permeability tuning in the broadcast bands. Similar side-molded units are now available for short wave frequencies including television and frequency modulation.

As the name implies, cores of this type are molded by applying pressure from the sides rather than from the ends. The resulting units show very little variation in density or permeability with respect to length, thus assuring a high degree of uniformity.

WRITE FOR CATALOG! *Other Stackpole Iron Core types include both standard and high-frequency types; insulated types; iron cores for choke coils, etc. Our new Catalog RC6 describes these as well as fixed and variable resistors, and our complete line of inexpensive line, slide, and rotary-action switches.*

STACKPOLE CARBON COMPANY, ST. MARYS, PA.

STACKPOLE

IRON CORE HEADQUARTERS

MILLIAMPERES D.C.
TRIPLETT
AMPERES R.F.
AC OR DC
Any Size
2" – 3" – 4" – 5" – 6" – 7"
Any Style
Shipment within 30 days
ON any AA Priority
The Triplett Line of Instruments—a complete line from one source and better than ever before—is now ready for the demands of "regular" business. Naturally, standard catalog numbers ready in the stock room can be shipped promptest, but all our instruments, through increased production facilities, are being delivered with gratifying speed. You can count on quick deliveries so place your orders now.
Triplett
ELECTRICAL INSTRUMENT CO.
BLUFFTON OHIO
STANDARDS ARE SET BY TRIPLETT

CHARACTERISTICS:

In single phase circuits, full wave rectification can be obtained with good regulation with a circuit that supplies 5000 volts D.C. at 3 amperes, with no indication of arc back

PEAK INVERSE VOLTAGE:

Cond. mercury temp. 20° to 50°c = 15,000 v
Cond. mercury temp. 20° to 60°c = 10,000 v

Max. peak plate current—amps—6. Max. Average Plate current—amps—1.5 Filament—5 volts—10 amps

TYPICAL CIRCUIT CONDITIONS

Single phase full wave	(2 tube)	5,000	3 amps
Single phase bridge	(4 tube)	10,000	3 amps
Three phase half-wave	(3 tube)	7,500	4.5 amps
Three phase par. Double Y	(6 tube)	7,500	9 amps
Three phase full wave	(6 tube)	14,500	4.5 amps

We SPECIALIZE in INDUCTION HEATING TUBES

(IMMEDIATE Delivery)

In addition to the ARPIN 575-A, we recommend four additional tubes for industrial heating applications which have met with widespread approval. These are the ARPIN Nos. 875-B, 892, 869-B and 95-T. Write for Characteristic Sheets of these tubes, or

Write for the NEW ARPIN CATALOG . . . illustrating and describing all new, current ARPIN Tubes.

ARPIN MANUFACTURING CO. 422 ALDEN ST. ORANGE, N. J.

Profession by Dr. A. H. Carter, American Medical Association.

Electroencephalography by Dr. Ralph Girard, University of Chicago.

Recent Theoretical Developments in Electronics

Theory of Microwave Oscillation Generators Using Velocity-Modulated Electron Beams by Dr. E. U. Condon, Westinghouse.

Theorem of Lorentz for Electrons in Magnetic Fields by Dr. Leon Brillouin, Columbia University.

Transient Response of Wide-Band Amplifiers by Dr. W. W. Hansen, Sperry.

Underground Communications Center

IN ENGLAND, two years before D-Day, work was started on a combined signal headquarters for American, British, and Canadian forces. One hundred feet beneath the English countryside, this center is a town in itself. Radio facilities are such that complete direction of the battle in France could be exercised from this point.

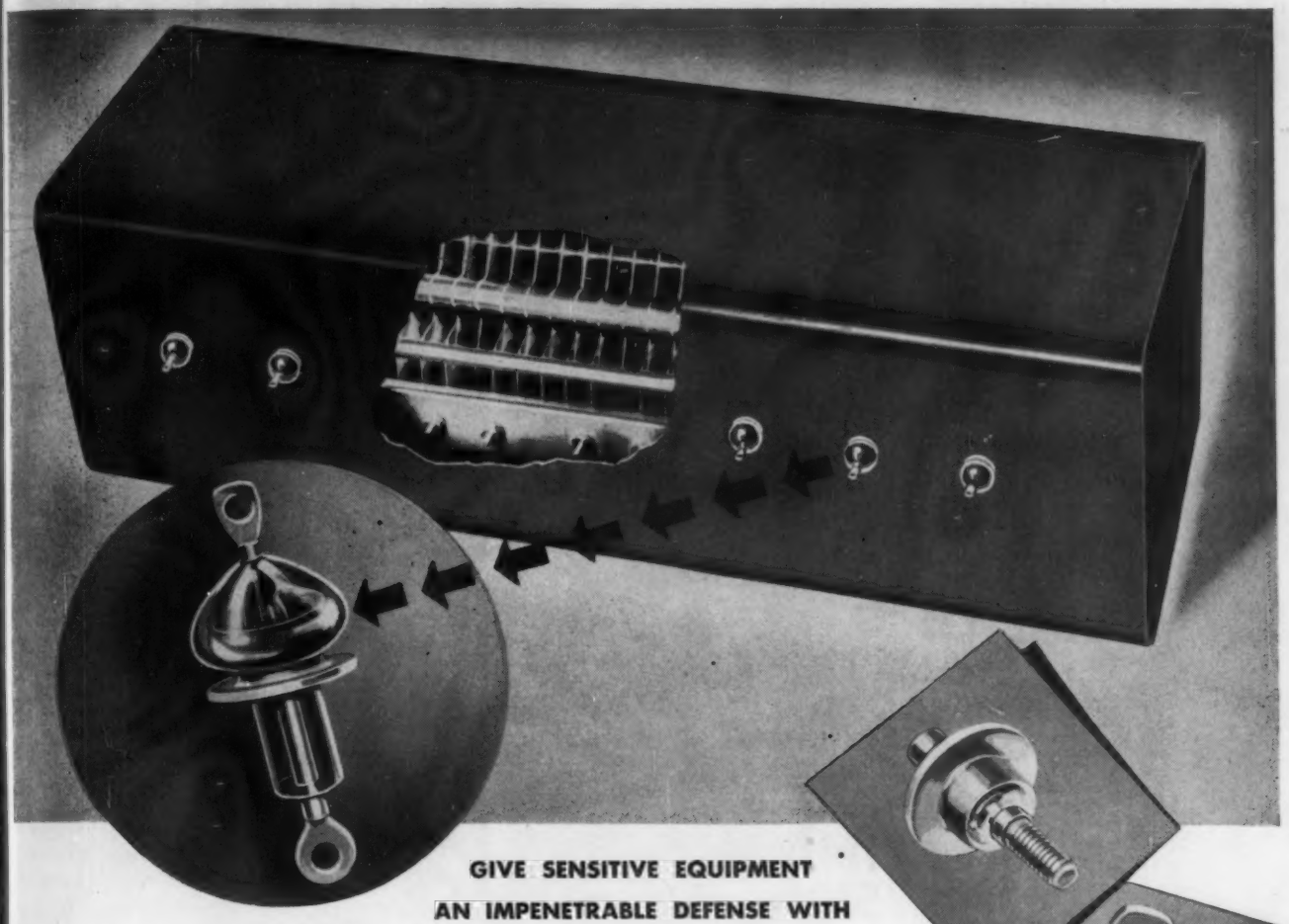
Television Course for Radio Engineers

DURING OCTOBER, NBC will sponsor, in New York, a special four-week course in television for the engineering personnel of its affiliated stations. Given under the direction of the RCA Institute, the course will be composed of field trips alternating with lecture classes. Subjects will include major elements of television systems; remote television pickups, cathode-ray tubes and oscilloscopes, kinescope deflection methods, analysis of television receivers, studio design and arrangement, iconoscopes and orthicons, analysis of control pulses, wide-band line amplifiers, television transmitters, and television developments and trends. Other features will include inspections of live-talent studios in Radio City and of the transmitter in the Empire State Building.

Unionists Learn Electronics

FEELING THAT ELECTRONICS is about to become the dominant part of the electrical industry and run into four billion-dollar proportions, the International Brotherhood of Electrical Workers (AFL) is working with the Engineering College of Marquette University to establish a national electronics school for its membership.

Intensive six-week courses are to be given to 700 men a year, each of



GIVE SENSITIVE EQUIPMENT
AN IMPENETRABLE DEFENSE WITH

Sperti Hermetic Seals

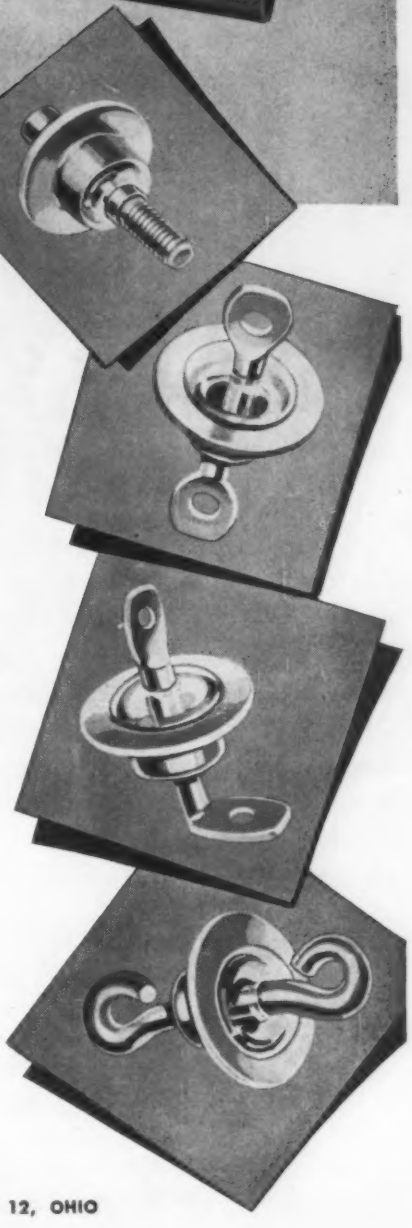
Volume production! Prompt deliveries!

Block the only points of entry for dust, fungus, moisture and other external elements that threaten the efficiency of equipment under tough military conditions. Adopt Sperti Hermetic Seals for capacitors, condensers, inductances, relays, vibrators, transformers and other component parts.

ONE PIECE. Glass and metal are fused into one piece to form a vacuum-tight hermetic bond. Resist corrosion. Have a thermal operating range of –70° C. to 200° C. Insulation leakage resistance, 30,000 megohms, minimum, after Navy immersion test.

SOLDERING TEMPERATURE NOT CRITICAL. Simple, easy to attach by means of high frequency, oven-soldering or standard soldering iron.

WIRE, WRITE OR PHONE TODAY for information. Full details of planned use of Sperti Hermetic Seals will bring proper recommendations and desired samples, promptly.



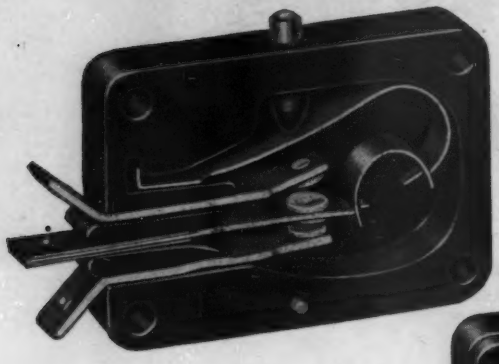
Sperti INCORPORATED

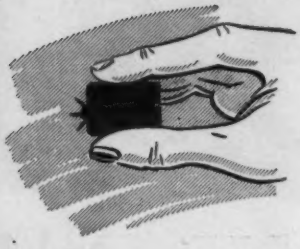
Electronic Division, Dept. E-4

RESEARCH · DEVELOPMENT · MANUFACTURING · CINCINNATI 12, OHIO

The Smallest *Fully Enclosed* SWITCH

IN PRODUCTION AND USE!





The Acro Miniac

This NEW ACRO MINIAC—the smallest fully enclosed snap-action switch in production and use — is built with the well-known patented ROLLING SPRING that eliminates friction, maintains higher contact pressure and prolongs life.

Built with a bakelite case, it is only 1-3/16″ long, 13/16″ wide and only a trifle over 1/4″ thick. Designed with 4 mounting holes 3/32″ diameter. Unusually well adapted for stacking in multiple assemblies. Stainless steel pin actuator. All parts are non-corrosive. All contacts are of fine silver. Blades and rolling spring of beryllium copper. Single pole, normally open or normally closed and double throw. Available with air gaps, .010″ to .040″. Standard operating pressures in 3 ranges from 5 oz. to 20 oz.

RATED AT 15 AMPS., 115 VOLTS, A.C.
Write for details today.

ACRO ELECTRIC COMPANY

1316 Superior Avenue, Cleveland 14, Ohio

New York, Chicago, Buffalo, Detroit, Dallas, Omaha, St. Paul, Kansas City, Memphis, Tampa, Baltimore, New Orleans, Phoenix, Los Angeles, Dayton, Toronto, Canada

whom will return to his local union as an instructor to pass the information along to some 25,000 members per year. Tuition costs of the electronics school amount to about $30,000 a year, which will be taken care of by the international union. Locals will bear the expense of transporting and lodging their member students.

Tubes for Civilians

AT LEAST ONE HUNDRED and possibly 200 percent more civilian radio tubes will be delivered in the last half of 1944 than in the first half, according to an estimate of Arthur Stringer, director of circulation for the National Association of Broadcasters. Increased production is actually in effect and between 35 and 40 percent of the increase is expected to be shipped during the third quarter of the year.

Listing of Licensees

NAMES OF 600 HOLDERS of first- and second-class radiotelephone licenses comprise a list released by FCC in a third report on its survey of manpower. These licensees have indicated availability for employment in the communications industry.

Besides the names and addresses of the individuals, their present draft status, the nature of their present employment, the class of license held, and other particulars are listed. The compilation is broken down by state of residence and by census regions.

Radio Telephone for Emergency Airport Vehicles

CONSTRUCTION PERMITS for low-power experimental radiotelephone stations in crash trucks, ambulances, and fire trucks have been granted by FCC to Lockheed Air Terminal, Inc. Authorized for transmission above 100 Mc, the installation will be in the vicinity of the company's airport at Burbank, Calif.

Communications on Attu

U. S. FORCES OCCUPYING the Aleutian Island of Attu found no evidence of the use of radio there by the Japanese. Stories to the effect that the Japs used high-pitched bird-call whistles to give signals

If you make temperature responsive devices for any purpose, then some one of the 35 different types of Chace Thermostatic Bimetals will exactly meet your needs for the actuating element. Each type of Chace Thermostatic Bimetal is especially engineered to meet specific conditions . . . each will produce known action at a predetermined temperature . . . all are very economical . . . and always dependable.

Let Chace help you select the most efficient type of bimetal for your control.

W.M. CHACE CO.
Manufacturers of
Thermostatic Bimetals and Special Alloys
1630 BEARD AVE • DETROIT 9, MICH.

have not been substantiated and such sounds are now thought to have been actual bird calls which are still heard daily. These facts were contained in a report recently received by Major General H. C. Ingles, Chief Signal Officer.

New Coaxial Run

AMONG FACILITIES which may be available for a postwar television network is a new coaxial cable link, authorized by FCC between Terre Haute, Ind. and St. Louis, Mo. Permission was granted to AT&T for construction of this new circuit which will contain six coaxial conductors. Cost of the overall project is $4,032,000, including carrier equipment to be installed at points between Kansas City and New York. The installation wil provide 226 additional telephone channels which are now urgently needed for war messages.

Supplementary Service Survey

ALL DOMESTIC BROADCAST stations including fm and television are being circularized by NAB (National Association of Broadcasters) to obtain information which will aid in estimating present and future needs for frequencies devoted to relay, studio-transmitter link, experimental, and emergency use. Resulting information will be tabulated and made available to the various RTPB panels dealing with allocation problems. Individual information will be kept confidential.

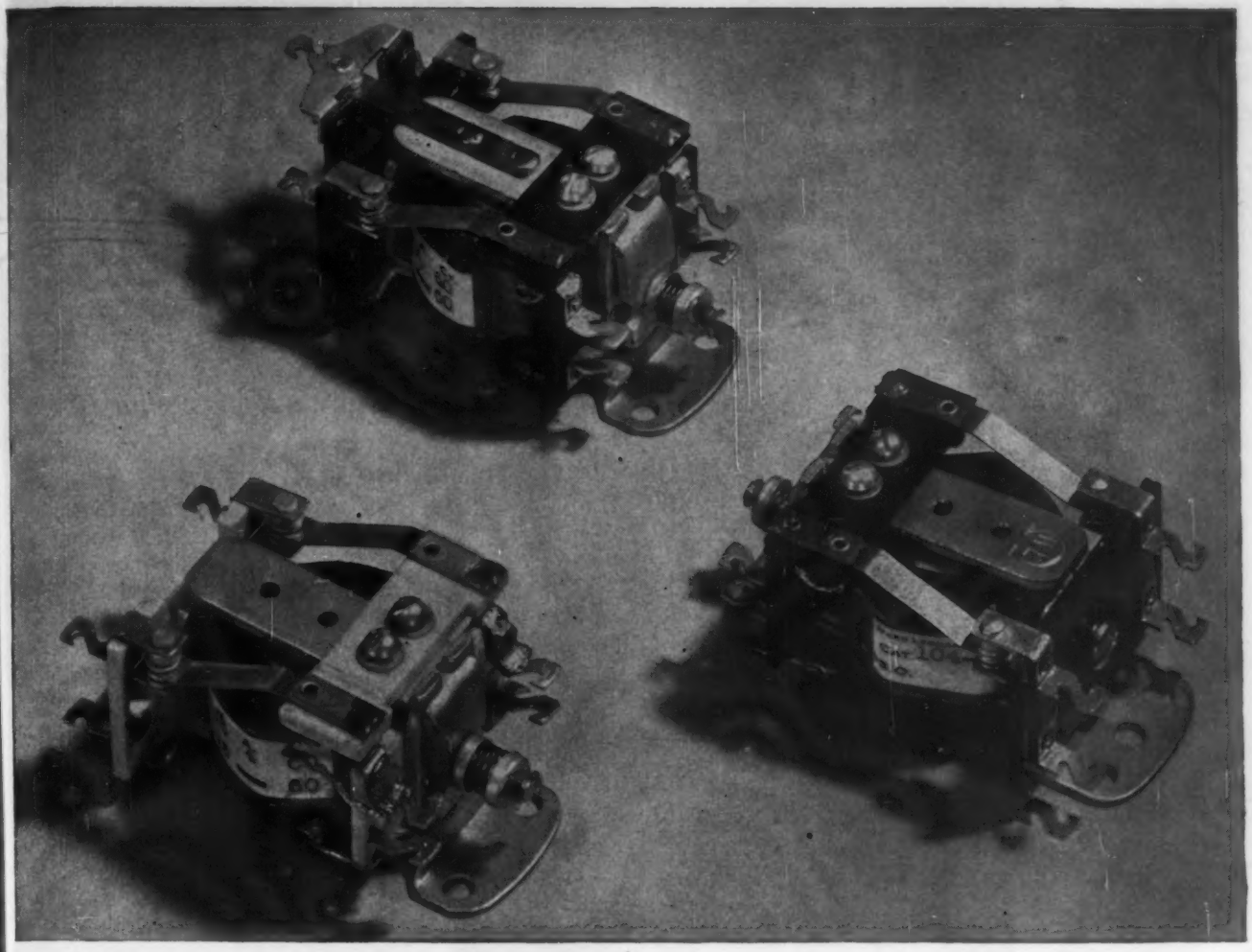
Radiation Patents

AT THE RADIATION LABORATORY of Massachusetts Institute of Technology, the Signal Corps has established the Cambridge Signal Patent Agency with responsibility for the preparation of patent applications related to work at the Radiation Laboratory and at the Radio Research Laboratory of Harvard University.

Canadian Radio

POWER INCREASES have recently been approved by Canadian Broadcasting Corp. for a dozen or so transmitters. Lack of material is delaying the approved changes.

Other applications have been made and approved for a number of



ADAPTABLE...

FOR MANY PURPOSES

The Ward Leonard Midget Metal Base Relay has proven so satisfactory and dependable that several adaptations have been made in it to give it even wider application. The relays shown above are the original relay, one with auxiliary contact and one with porcelain insulation. These relays may be furnished with studs in place of metal bases.

Only 1¼ inches in height. For continuous operation on AC and DC voltages up to 110-115. Double pole, double throw. This Relay described in data Bulletin 104. Send for a copy.

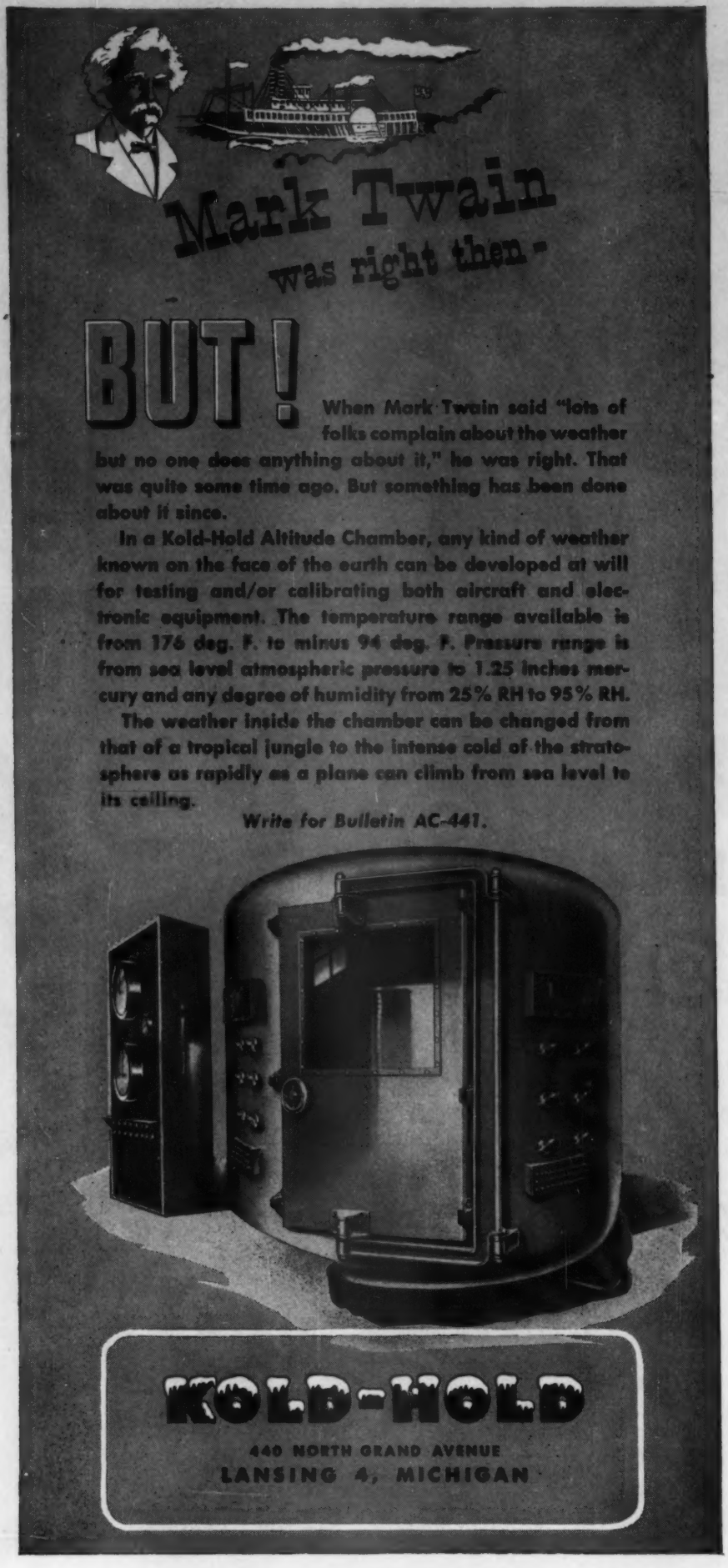
ARMY E NAVY

WARD LEONARD

RELAYS • RESISTORS • RHEOSTATS

Electric control (WL) *devices since 1892.*

WARD LEONARD ELECTRIC COMPANY, 32 SOUTH STREET, MOUNT VERNON, N. Y.


Mark Twain
was right then -
BUT!
When Mark Twain said "lots of folks complain about the weather but no one does anything about it," he was right. That was quite some time ago. But something has been done about it since.
In a Kold-Hold Altitude Chamber, any kind of weather known on the face of the earth can be developed at will for testing and/or calibrating both aircraft and electronic equipment. The temperature range available is from 176 deg. F. to minus 94 deg. F. Pressure range is from sea level atmospheric pressure to 1.25 inches mercury and any degree of humidity from 25% RH to 95% RH.
The weather inside the chamber can be changed from that of a tropical jungle to the intense cold of the stratosphere as rapidly as a plane can climb from sea level to its ceiling.
Write for Bulletin AC-441.
KOLD-HOLD
440 NORTH GRAND AVENUE
LANSING 4, MICHIGAN

local private stations and a new CBC station.

Two 50-kw shortwave transmitters are announced as being installed in New Brunswick for transmission to South America, Africa, Australia, and the Far East. Over these stations, which represent Canada's first venture into overseas broadcasting, programs will be brought from Montreal, 600 miles away.

Jeep-Mounted Mobile Cinema

FOR SHOWING MOTION PICTURES in battle areas, Warrant Officer Albert A. Hinchey established a workshop in New Guinea where projection equipment could be serviced. He also combined equipment with the necessary power supply so it could be mounted or a jeep for transport by plane to troop concentrations in areas inaccessible by road.

As a result of this activity, jeep-mounted RCA equipment was showing movies on Lae 48 hours after the island had been captured from the Japanese.

D.C. BIAS

Communications Construction. An amendment has been issued by FCC extending the time limit prescribed for facilities which have been authorized. Section 63.05 of the rules and regulations now state that "Unless otherwise determined by the Commission upon proper showing in any particular case in the event construction shall not have been begun upon a project involving an expenditure of more than $50,000 within 12 months from the date of the Commission's authorization, or all or part of the proposed facilities shall not have been placed in operation within 36 months after such date, such authorization shall terminate at the end of such 12 or 36 months period . . .". For projects involving $50,000 or less, the time periods are 9 months or 18 months.

Production Deficit. Since the principal deficits in deliveries of military products are in those items most urgently needed in combat areas, the Army has asked for increased efforts by management and labor to bolster up lagging pro-

An Army that Travels on its Ears

CERTAINLY, today's armies have Stomachs, but they have something Napoleon's armies *did not* have . . . Ears. Ears that can hear, not for just a few feet, but over any distance on Land, in the Air and on the Sea. Electronic ears that link every unit of our fighting forces in instant and complete Communication . . . that spell the difference between success and failure.

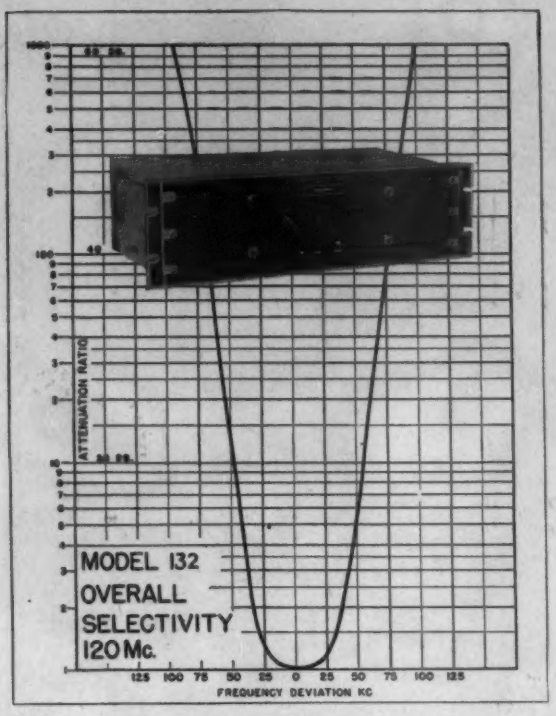
As a pioneer designer and manufacturer of Sound Reproducing Equipment, it is only natural that Rola should be in the forefront of the effort to supply our Military with the delicate, dependable components for Communications Systems... Headsets, Transformers, Coils and other Electronic parts. Knowing the power of Communication on the Home Front, it is only natural that Rola suggests, "Consider everything you SAY; check the source of everything you HEAR."

THE ROLA COMPANY, INC. • 2530 SUPERIOR AVENUE • CLEVELAND 14, OHIO

ROLA

Let's do more ARMY E NAVY *in forty-four!*

MAKERS OF THE FINEST IN SOUND REPRODUCING AND ELECTRONIC EQUIPMENT



Performance

Comco Receiver
MODEL 132

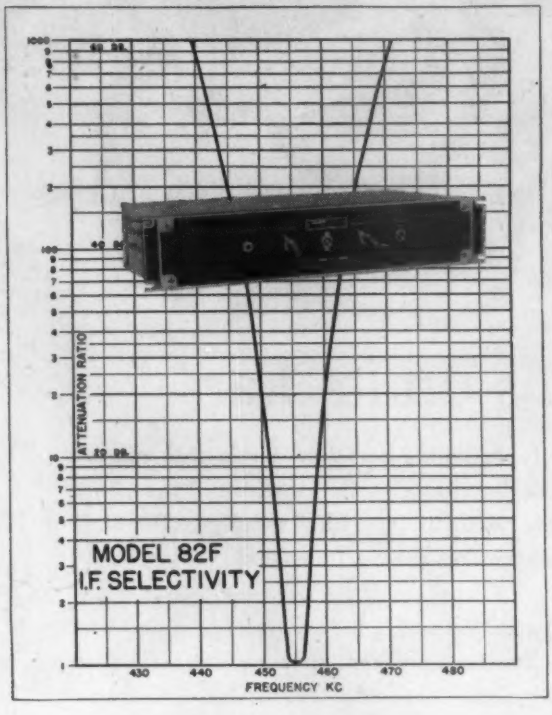
Frequency Range:
100 — 156 Mc.

Image Ratio:
300 to 1 (50 db.) at 100 — 128 Mc.
100 to 1 (40 db.) at 128 — 156 Mc.

A.V.C. Action:
Constant within 3 db. from 100 microvolts to 100,000 microvolts

Sensitivity:
7.5 microvolts 30% modulated for 6 mw. output

Signal-to-Noise:
13 db. at 7 microvolts Input 30% modulated



Comco Receiver
MODEL 82-F

Frequency Range:
2.0 to 8.0 Mc.

Image Ratio:
50,000 to 1 (94 db.) at 2.5 Mc.
55,000 to 1 (95 db.) at 3.6 Mc.
45,000 to 1 (93 db.) at 4.8 Mc.
10,000 to 1 (80 db.) at 6.5 Mc.

A.V.C. Action:
Constant within 3 db. from 10 microvolts to 1 volt

Sensitivity:
3 microvolts 30% modulated for 50 mw. output

Signal-to-Noise:
9 db. at 3 microvolts Input 30% modulated

THE radio telephone receivers illustrated above are of the fixed tuned, crystal controlled, superheterodyne type, for aeronautical ground stations, airport control towers, police radio stations or point-to-point service.

We invite your inquiries as to use of these receivers in conjunction with your present or post-war planning. Our facilities are at your service, whether you need complete transmitters, receivers, or some electronic component which we can help design and manufacture for you.

COMMUNICATIONS COMPANY, Inc.

Manufacturers of Radio and Electronic Equipment

CORAL GABLES — COMCO — 34, FLORIDA

duction. Radio and electronic equipment is in this category. Materials in production today are required to meet expenditures on the battle front, and failures now to meet schedules mean delays in military operations which may be costly in loss of lives and in prolonging the struggle.

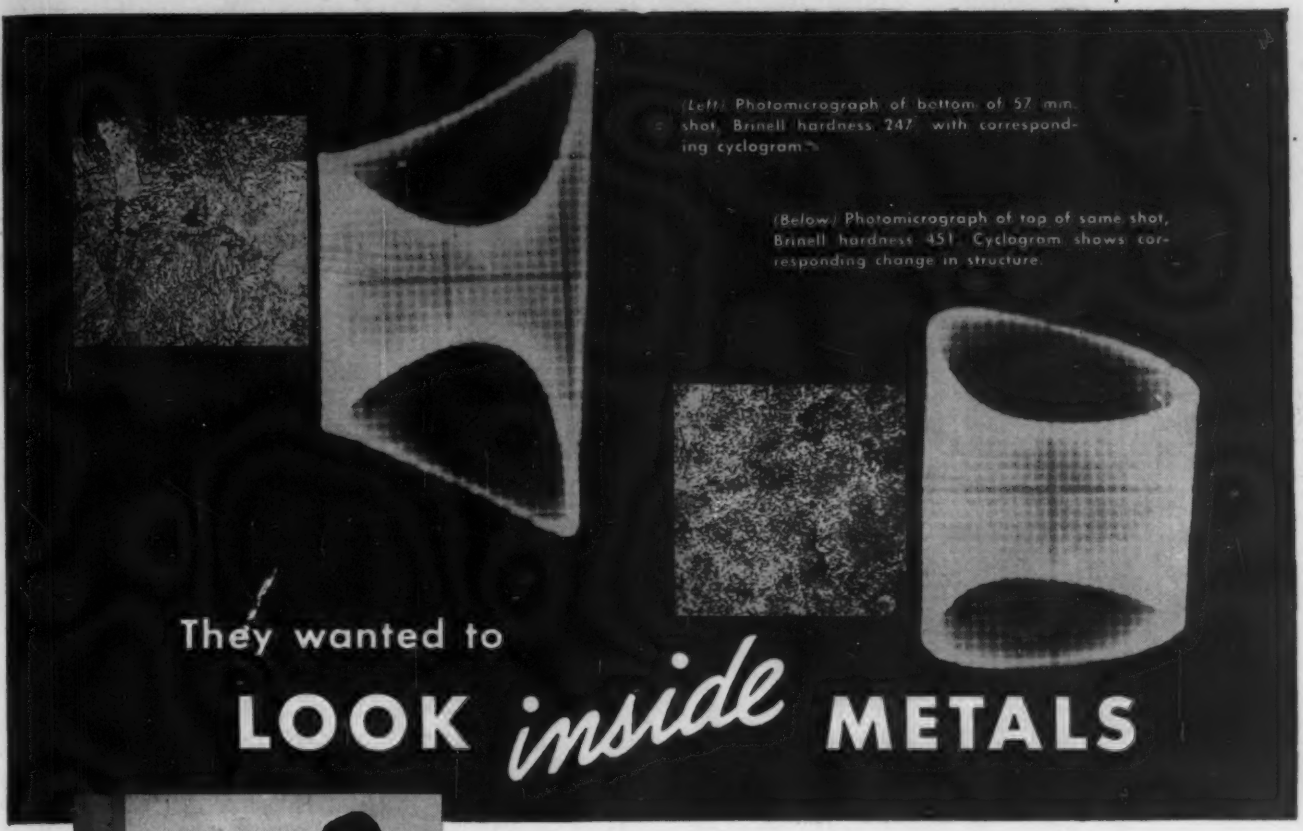
Meanwhile, WPB has made increased efforts to channel idle and excess electronic components back into the production stream. Forms have been sent to all radio prime contractors and component manufacturers, so that they can report excess and idle stock. The component recovery section of WPB will maintain distribution of published idle-and-excess-component listings.

Surplus Disposal. An orderly method of handling future huge quantities of electronic surpluses is expected to result from present tests on ways of handling currently small amounts of products by Defense Supplies Corp. Among specific problems anticipated are those surrounding the disposition of obsolete walkie-talkies and similar equipment which, unless care were exercised, might end up in the hands of criminals or other subversive elements.

Mica. At recent meetings of the raw mica fabricating industry advisory committee, methods were discussed for obtaining and conserving the better qualities of mica, for manufacture of block mica into film, and for establishment of standards. Questions covered included the advisability of changing the dividing line between strategic and non-strategic block mica, while relaxation of unnecessary controls was advocated by industry representatives.

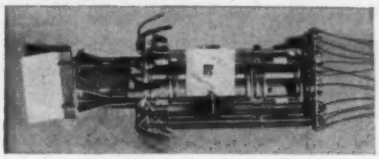
It was reported that large stocks of No. 6 mica of better qualities (good stained, fair stained, clear, and slightly stained) are now available for all purposes. Radio tube manufacturers were urged to use the better quality even though prices of finished tube parts might increase. Greater consumption of No. 6 mica would be beneficial in relieving pressure on No. 5 and 5½ for radio and radar capacitors.

To help the industry acquaint itself with the various micas available, tentative plans call for 100-lb samples of each quality to be main-


(Left) Photomicrograph of bottom of 57 min. shot. Brinell hardness 247 with corresponding cyclogram.
(Below) Photomicrograph of top of same shot, Brinell hardness 451. Cyclogram shows corresponding change in structure.

They wanted to LOOK *inside* METALS

GOOD *bad* GOOD GOOD *bad*... 6,500,000 bullets, rejected because of a mix-up in copper cladding measurements, were re-sorted by the DuMont Cyclograph... 99% of them salvaged!



ALL METAL PARTS OF CYCLOGRAPH TUBES ARE *NICKEL & NICKEL ALLOYS*

... Nickel is de-gassed readily ... has strength to endure de-gassing bombardment at 1850° F.

It resists warpage and distortion ... has high stiffness and damping capacity to minimize vibrations of delicate parts.

It does not rust ... is highly resistant to corrosion.

When carbonized, it supplies ductile easily-formed strip of very high thermal emissivity.

The high work function of Nickel minimizes back emission.

It is unsurpassed as a base for stable, oxide coated cathodes of high electron emissivity and long life.

It resists deformation in handling during manufacture ... makes strong spot welds and resists oxidation during welding.

... and DuMont Laboratories found that pure Nickel and Nickel alloys provided all the properties they sought to make the electronic eyes of their Cyclograph

The Cyclograph gives an immediate electronic view of the inner make-up of metals.

Its cathode-ray tube reveals differences in magnetic and electrical properties of metals which may be correlated with differences in one of the following: chemical composition, hardness, toughness, internal stresses, case depth, thickness of plating or cladding, and other characteristics.

These readings, to be accurate, require cathode-ray tubes free from tube-caused errors which might affect the Cyclogram.

Naturally the cathodes of DuMont cathode-ray tubes—as in the majority of modern tubes—are pure Nickel.

For Nickel provides the combined mechanical, electrical and electronic properties which give the DuMont cathode-ray tube its long life.

This use of pure Nickel and other Nickel alloys in the DuMont cathode-ray tube is typical of the unique service given by Nickel and its alloys, for Nickel alloys offer the electrical, expansion, magnetic and non-magnetic characteristics required in electronic devices.

If you have a problem involving the selection of the right metal for an electronic application, you are invited to consult INCO Technical Service. Address: The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

NICKEL INCO ALLOYS

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • NICKEL • "Z" NICKEL

Sheet ... Strip ... Rod ... Tubing ... Wire ... Castings

Facts YOU SHOULD KNOW ABOUT RELAY SENSITIVITY

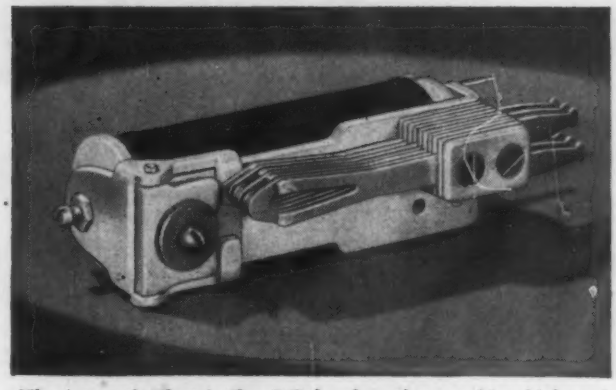
SO YOU would like a *sensitive* relay for that remote control circuit!

Sensitivity is important for many relay applications. And if that is *all* you want, there's no problem. It's easy to build a relay that will "operate" on a small amount of power.

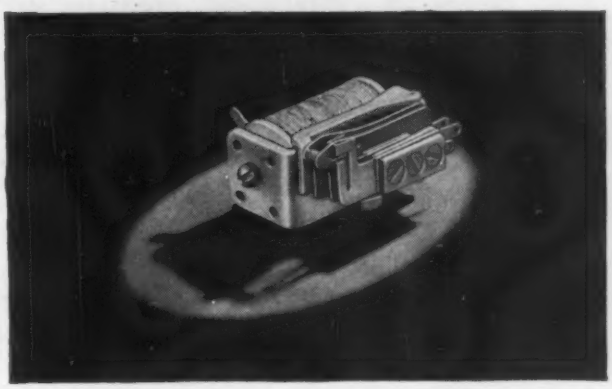
But sensitivity without contact reliability is useless. So what you *really* want is a relay that is not only sensitive, but also has the contact pressure needed for reliability under actual service conditions.

Sensitivity and contact reliability are opposing factors. To get a high measure of both qualities in one relay calls for an exacting balance between electrical, mechanical and magnetic design factors. We've been building such relays for years —to meet hundreds of requirements, from complex telephone switching circuits to simple control functions on aircraft and radios.

Next time you need a *sensitive* relay, let the Automatic Electric field engineer show you how to get sensitivity *plus* contact reliability. No matter what the nature of your problem, there is an Automatic Electric relay that will give you both.



The Automatic Electric Class B Relay shown here combines high sensitivity and contact reliability. It has a highly efficient magnetic circuit, long wearing mechanical structure, independent twin contacts, and capacity for any number of springs up to 26. Contact pressures average 20 grams per contact. Compare this with "sensitive" relays having contact pressures of less than five grams.

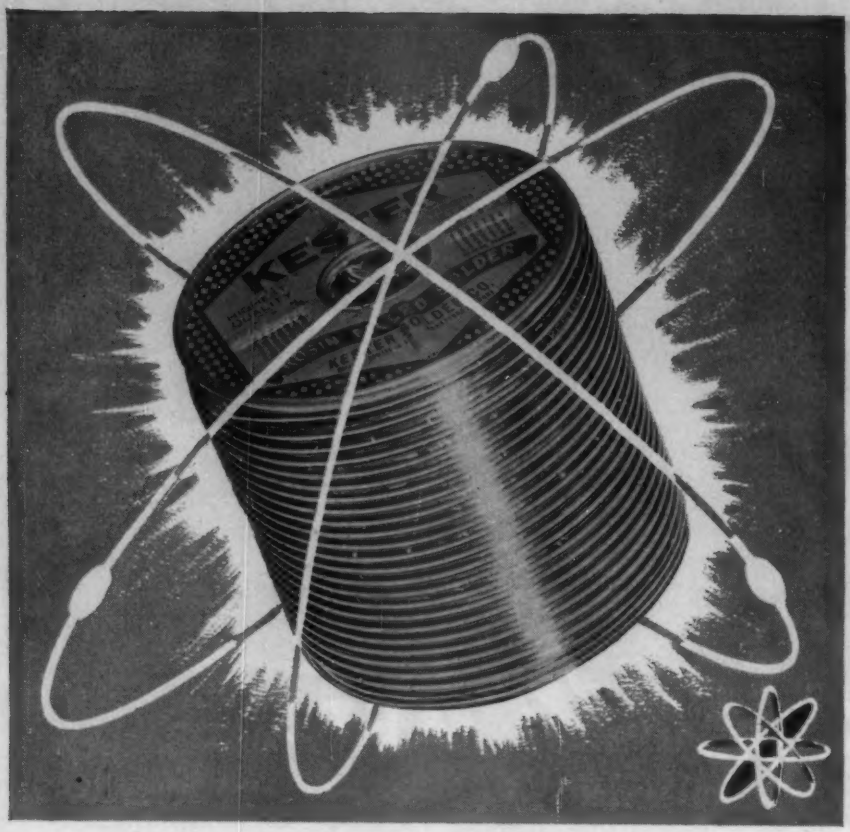


For high sensitivity and contact reliability in small space, your best bet is the Class S Relay shown here. Especially designed to meet the severe conditions of operation on fast modern aircraft, it is also recommended where space is at a premium. Because of the great demand for Class S Relays for vital war products, we urge that you avoid its use except where no other relay will serve.

Relays AND OTHER CONTROL DEVICES by AUTOMATIC ELECTRIC

AUTOMATIC ELECTRIC SALES CORPORATION
1033 West Van Buren Street • Chicago 7, Ill.

In Canada: Automatic Electric (Canada) Limited, Toronto



KESTER, The Right Solder for an Exacting Job

● Solder used in building and assembling electronic equipment must be *right*. The successful operation of the unit as a whole often hinges upon this important factor.

● Kester Rosin-Core Solder is *right* for safeguarding electronic circuits. The patented, plastic rosin flux, especially compounded for this type of soldering, is self-contained in the core of the alloy in proper amount for perfect results. It will not cause corrosion or injure insulating material.

● In the wide range of Kester core and strand sizes, there is one combination exactly suited to your requirements. Consult Kester engineers—they'll gladly assist you in working out the *right* solder formula for your plant operation. Write fully—there's no obligation.

KESTER SOLDER COMPANY

4204 Wrightwood Avenue — Chicago 39, Illinois

Eastern Plant: Newark, N. J. — Canadian Plant: Brantford, Ontario

★ BUY WAR BONDS ☆

Finest Quality FOR 45 YEARS 1899-1944 KESTER SOLDER

KESTER Cored Solders STANDARD FOR INDUSTRY

tained for inspection at New York and Washington. Capacitor manufacturers were urged to call the attention of their customers to the desirability of using capacitors of low-quality mica in place of paper-dielectric units. Only one-third of available mica-capacitor facilities are being utilized at present.

Dry Cell Batteries. Consumers durable goods division of WPB is pointing out to distributors of farm radio batteries that such products have, within the past year, become one of the most urgent and critical products in our war production program. Military requirements were described as exceeding production by an estimated 30 percent. Because fifty or more military items such as radios, buoys, submarine detectors, direction finders, bazookas, and field telephones require dry batteries, it is unlikely that the industry will be able to do any more than maintain the present inadequate civilian production. The production bottleneck was indicated as being a shortage of workers rather than a shortage of materials or machines.

BUSINESS NEWS

In the theater equipment business, RCA Victor Div., **Radio Corp. of America,** plans postwar distribution on a worldwide basis not only of sound reproducing equipment but also related theatrical apparatus.

Illinois Condenser Co. increases its production to a point 300 percent above activities a year ago by addition of a floor to its Chicago plant.

Two department heads at **Kollsman Instrument Co.,** Flushing, N. Y., found themselves in court recently for breaking an obscure ordinance which prohibits working on Sunday—even for an Army-Navy E.

Labor-management committeemembers at **Hallicrafters Co.,** Chicago, Ill., turned over to the Army's new Vaughan General Hospital the $2500 that employees would have been paid for working

Built to take it . . . *anywhere* . . . *anytime!*

●●●● Techrad LRR-4 is built to take it under any and all conditions. This Techrad receiver has F.C.C. approval for low radiation, but there are many more reasons why it is winning such general acceptance.

Techrad LRR-4 is built to insure uninterrupted performance under the most drastic conditions of service . . . *anywhere in the world.* Because of its massive and rugged construction, it can be counted on to get there, and to get there intact. It will stand transshipment on the bang-slam carriers found in remote places and be ready to go into service upon arrival at its destination.

Techrad LRR-4 will work in any climate. It offers a high degree of resistance to tropical humidity and to tropical organisms because *LRR-4 transformers are hermetically sealed* . . . and *LRR-4 wiring and terminal boards are completely Anti-Fungus treated.* It will also stand up under severe duty at sea, because *LRR-4 is capable of withstanding the Salt Spray Test.* Techrad LRR-4 is available in a number of different models which cover a variety of frequency ranges.

TECHRAD

• • • •

MASTER ENGINEERING TAKES NOTHING FOR GRANTED.

Technical Radio Company

Over ten years of continuous experience

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*DOUBLE-LOCKING ACTION

When the PALNUT is tightened, its arched, slotted jaws grip the bolt like a chuck (B-B), while spring tension is exerted upward on the bolt thread and downward on the part (A-A), securely locking both.

Provides unfailing security with Savings in Time, Cost, Weight, Space

Years of successful use on Radio and Electronic equipment have proved that the double-locking action* of PALNUTS holds tight under vibration, eliminating need for slower, heavier, more expensive nut-and-lockwasher assemblies.

With this dependable security of PALNUTS, you also cut the cost of fastenings in half—reduce assembly time 50%—save up to 90% in weight—require less space.

PALNUTS are single thread locknuts, made of spring tempered steel. Speedily applied with Yankee or Power Drivers. Available in a wide range of types, sizes and finishes.

Send details of your assembly for samples. Write for Palnut Manual No. 2 giving complete engineering data.

THE PALNUT COMPANY, 77 Cordier St., Irvington 11, N. J.

extra time on D-day, plus $2500 they would have spent on a company picnic they cancelled.

Madison Electrical Products Corp. is a new company in Madison, N. J., devoted to manufacture of resistors, electronic assemblies, coil windings, and special components.

By producing in a single plant more than 4,178,000,000 single-conductor-feet of wire, during the last 2½ years, **United States Rubber Co.** exceeds the combined industry figure for building wire in 1941.

West Coast Electronic Manufacturers Association accepts for membership six new concerns, bringing the roster above the fifty mark. The companies are **Brittain Sound Equipment Co.**, Los Angeles; **Merle F. Faber**, San Francisco; **Harvey Machine Co.**, Los Angeles; **Howard Pacific Corp.**, Los Angeles; **The Lake Mfg. Co.**, Oakland; and **Special Electric Laboratories**, Los Angeles.

Electronic equipment for the armed forces will be manufactured by approximately 2000 workers of **Western Electric Co.**, in newly leased space at 529 West 42 St., the company's fourth manufacturing plant in metropolitan New York.

Universal Microphone Co., Inglewood, Calif., purchases the entire plant in which it has been operating under rental for the past 12 years. Included are two two-story buildings, an annex, and two stores.

Home receivers are reported to be planned as part of the postwar line of the radio division of **Bendix Aviation Corp.**

Under a system referred to as the PDQ plan, **Emerson Radio & Phonograph Corp.** is establishing preference delivery quotas for home receiver sales after production is resumed. Priority certificates are issued without cash deposit to would-be consumers who register with dealers throughout the country.

National Broadcasting Co. is starting a 50-week course in television for the engineers in its central division. Instruction will be in charge of Clarence Radius, and will parallel that previously made

"The high quality of their product, which comprises telephones, switchboards and electrical supplies, has placed them in the position of the largest manufacturer of their goods in this section of the country."

. . . from
A CENTURY OF MERIDEN
published in 1906

If "skill to do comes of doing," this thirty-eight year old commentary explains the record of Connecticut Telephone and Electric in manufacturing telephones, switchboards, and electrical supplies for the military needs of this war.

We look forward to the *next* thirty-eight years, confident that this is the dawn of the most important era yet, in the development of communications, and every other branch of electrical science.

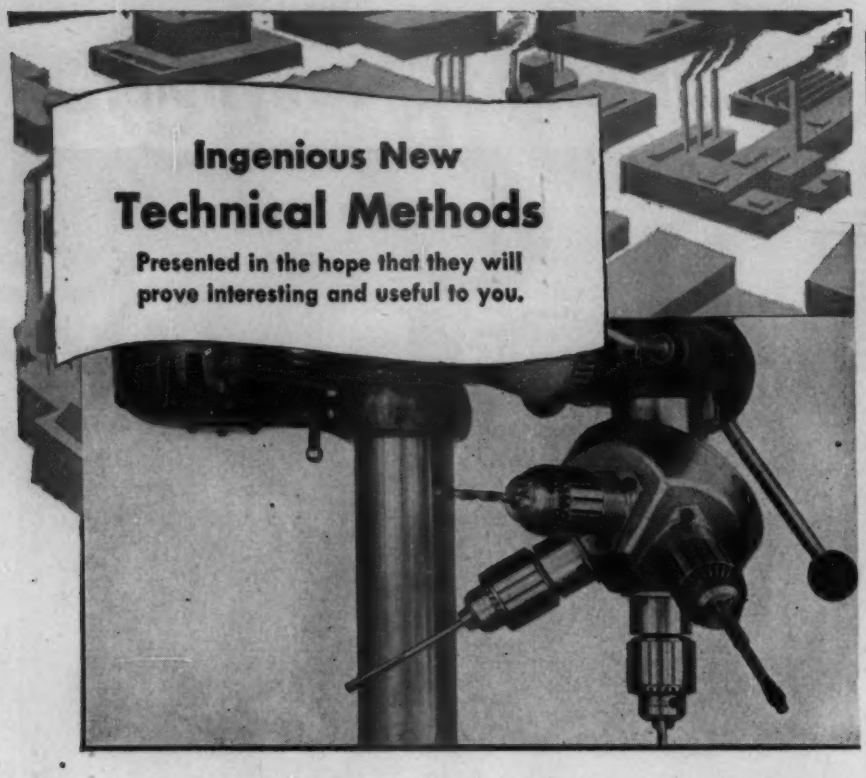
If our seasoned, but progressive, experience can be of help to you in connection with your communications requirements or the development and manufacture of electrical or electronic devices, we shall be glad indeed to talk with you.

CONNECTICUT TELEPHONE & ELECTRIC DIVISION

GREAT AMERICAN INDUSTRIES, INC.

MERIDEN, CONNECTICUT

TELEPHONIC SYSTEMS • SIGNALLING EQUIPMENT • ELECTRONIC DEVICES • ELECTRICAL EQUIPMENT • HOSPITAL AND SCHOOL COMMUNICATIONS AND SIGNALLING SYSTEMS • IGNITION SYSTEMS



Amazing New Four Spindle Turret Attachment for Drill Press!

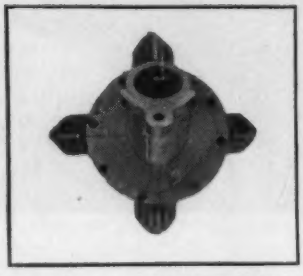
Now one drill press can do the work of four and, at the same time, effect a savings of up to 75% in floor space, with the "Quadrill" attachment. This rotary device will accommodate four boring or cutting tools at the same time, yet one tool *only* is in motion when the head is in operating position.

The entire unit is assembled to the quill of the drill press and is driven from the drill press spindle. Accuracy and rigidity of alignment of the "Quadrill" are assured by the special construction of the driver and spindles, thus efficiency is only limited by the accuracy and power of the drill press itself.

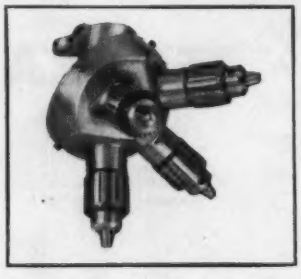
Foolproofing in indexing is accomplished by visual markings and by the relationship of the index pointers on the index disc, as well as the extension of the spring retainer. Four hardened and ground spindles are fitted for No. 32 Jacobs chucks or their equivalent. To provide correct positioning at all times, the entire spindle assembly is located by means of an accurate fitting of recess and undercut, between turret and bearing housings. The hardened friction starter and driver have been so constructed that at any speed proper synchronization of the driver teeth is accomplished without clashing.

It goes without saying that our fighting men must have the finest possible quality materials home industry can produce. So, although the stock of quality raw materials from which Wrigley's Spearmint chewing gum is made is growing steadily smaller, they are still maintaining pre-war standards. However, they can now make only a portion of their former output, so all of this limited production is going to our fighting men and women overseas only . . . where it is an "on-duty" need.

You can get complete information from Chicago Drillet Corporation, 919 North Michigan Avenue, Chicago 11, Illinois.



Quick and positive indexing assured by pointers on index disc



Quadrill assembly complete ready for attachment to drill press

Y-142

available to the company's eastern personnel.

Reorganization changes **Amperex Electronic Products** to a Delaware corporation, **Amperex Electronic Corp.**, gives it an affiliation with **North American Philips Co.** Personnel, management, and policies are unchanged except that former senior partner N. Goldman has retired.

A limited partnership, **Pioneer Gen-E-Motor** transfers all its assets and liabilities to a Delaware corporation, **Pioneer Gen-E-Motor Corp.**

RCA Victor Div., **Radio Corp. of America** is using 17,000 new procedures suggested by efficiency-conscious workers since Pearl Harbor. This represents 35 percent of all ideas submitted.

In a new building at Minneapolis, Minn., **Audio Development Co.** now houses its general and engineering offices, experimental and design laboratory, and model shop. Space formerly occupied by these units is assigned to production for a 25 percent increase.

PERSONNEL

Director of communications **J. R. Cunningham** rejoins United Airlines after more than two years of active duty with the AAF.

At newly-organized Grayhill, Chicago, Ill., **W. S. Lewis** fills the post of chief mechanical engineer, while **Arnold Wassell** heads up plastic design engineering.

W. C. Walsh, formerly electrical design engineer for the Department of Agriculture, becomes district representative of the General Electric electronics department in San Francisco, Calif.

Within RMA, 12 parts group are organized under the chairmanship of **Robert C. Sprague** of Sprague Electric Co. Heads of the various sections are: **Paul Hetenyi**, capacitors, Solar Mfg. Co.; **Leslie F. Muter**, coils, Muter Co.; **J. H. Stackpole**, fixed resistors, Stackpole Carbon Co.; **R. L. Triplett**, instruments, Readrite Meter Works; **Hugh H. Eby**, sockets, Hugh H. Eby, Inc.; **W. R. MacLeod**, special products, King Laboratories, Inc.;

This switch design required not only the characteristics of a laminated plastic, but also the desirability of molding it. Thus, the arc chamber is composed of four units of INSUROK — laminated and molded laminated, fibre faced. INSUROK was used because of its constant dielectric and physical characteristics; its resistance to corrosion and ability to withstand continuous hard usage.

How INSUROK helps a Bull Dog control arcs

By keeping the amount of oxygen necessary to support combustion out of the arcing chamber, the Bull Dog Vacu-Break Safety Switch eliminates destructive arcing —secures better rupturing performance, conductivity and safety.

The four INSUROK units in which the contacts "make" and "break" comprise a partitioned arc chamber. Because INSUROK Precision Plastics assure close fitting; because of their high strength and dielectric qualities; they protect and make an important contribution to the efficiency of this Vacu-Break Safety Switch.

INSUROK Precision plastics are available in a host of grades—in sheets, rods and tubes for fabrication in your own plant, or in completely finished molded or laminated parts or products. Perhaps it can solve one or more of your design problems, as it has thousands of others. For further information, consult Richardson Plasticians—without obligation, of course.

INSUROK

Precision Plastics

The RICHARDSON COMPANY

Robert A. O'Reilly, switches, Oak Mfg. Co.; **James M. Bennan,** transformers, Jefferson Electric Co.; **Russell E. Cramer,** variable capacitors, Radio Condenser Co.; **H. E. Osmun,** variable resistors, Centralab; **Ray F. Sparrow,** vibrators, P. R. Mallory & Co.; and **R. G. Zender,** wire, Lenz Electric Mfg. Co.

At Webster Products, Chicago, Ill., **R. J. Keogh** joins the engineering staff. He has been with Colonial Radio Corp. in a similar capacity.

A. Warren Norton, new president and general manager of Press Wireless, Inc., was previously manager of the Christian Science Publishing Co. He succeeds **Joseph Pierson,** founder and former president.

Sylvania Electric Products Inc. puts **Curtis A. Haines** in charge of plants at Mill Hall and Altoona, Pa.; Huntington, W. Va.; and Lexington, Ky., as general manufacturing manager.

American Institute of Electrical Engineers elects to presidency

Charles A. Powel, manager of headquarters engineering at Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. His predecessor was **Dr. Nevin E. Funk.**

T. H. Mitchell, lieutenant colonel in the Army Communications Service, is to succeed **William A. Winterbottom,** deceased vice president and general manager of RCA Communications Inc.

At Operadio Mfg. Co., St. Charles, Ill., **Harold H. Kingsbury** is made production-control manager over the company's three plants there.

Formerly chief of the audio and industrial section of the radio and radar division of WPB, **Glenn C. Henry** joins the sound equipment

As the field of Electronics broadens and new, more complex equipment goes into service the need for more accurate test and measuring instruments becomes greater. The war has lent great impetus to the progress of Electronics and has accordingly accellerated the development of Electronic instruments. Into the past two years have been crowded a normal ten years of technological progress.

Today the most advance developments are not being released for general use. However, today is not too soon for you to make your plans for post-war activity. And, along that line, you should make note of the fact that *-hp-* engineering is in the vanguard of electronic instrument developments.

Oscillators to test wide range television channels, new high frequency signal generators, special signal generators for F. M. use, new vacuum tube voltmeters . . . all providing split-hair accuracy for more exacting measurements and ruggedly constructed to perform in the field under circumstances of war, are examples which merely hint of the better things to come.

-hp- engineering is at your service, whether your problem is immediate or for post-war. Write today, there is no cost or obligation. Direct Canadian inquiries to Atlas Radio Corporation, 560 King Street West, Toronto 2, Canada.

HEWLETT-PACKARD COMPANY

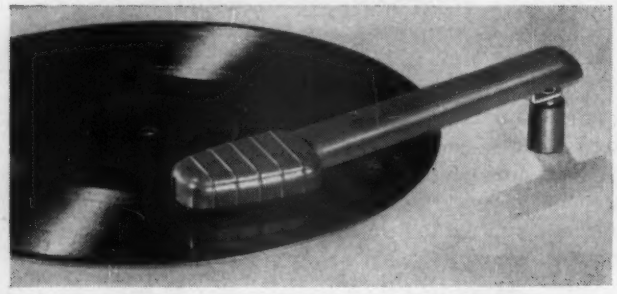
Box 927A Station A · Palo Alto, California

927

Making crystal pickups and cartridges has made Webster Electric Company outstanding in an industry that is never satisfied . . . always striving for something new . . . something better.

Dreams of tomorrow, like gazing into crystal balls, Webster Electric leaves to others. Our factories are busy with developments and research for victory. We need no crystal ball to know that Webster Electric will be ready with new . . . ever better . . . crystal pickups and cartridges to give even greater tone perfection to tomorrow's radio-phonographs.

When the day comes that many of the weapons of today become the everyday conveniences of tomorrow, Webster Electric's skill and experience will bring to the owners of radio-phonograph sets—to manufacturers, radio jobbers and dealers—new meaning in quality of tone reproduction.



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Established 1909. Export Dept.: 13 E. 40th St., New York (16), N. Y.
Cable Address: "ARLAB" New York City

WEBSTER ELECTRIC

"Where Quality is a Responsibility and Fair Dealing an Obligation"

LET'S ALL BACK THE ATTACK — BUY MORE WAR BONDS!

section of Radio Corp. of America where he will have responsibility for the development of products and services.

Dr. Edward U. Condon, associate director of the Westinghouse research laboratories is elected to membership in the National Academy of Sciences for his work in

theoretical physics. His best known contribution to this field is the interpretation of spontaneous emission of alpha particles from materials like radium.

John Meck Industries, Plymouth, Ind., has for chief engineer **Charles R. Wexler**, former assistant chief engineer at Emerson Radio & Phonograph Corp., and

C. R. Wexler

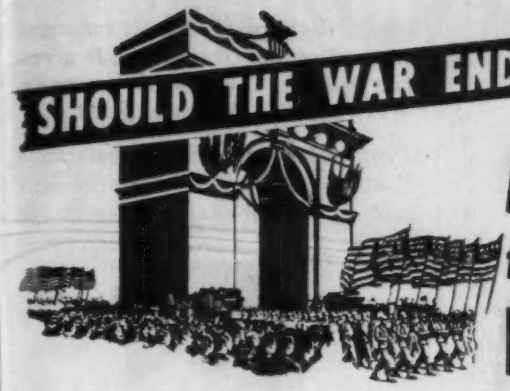
H. R. Denius

for plant manager of the electronic division, **Homer R. Denius**, previously chief production engineer for the radio division of Crosley Corp.

Communications consultant to the Iranian government is the new post of **James A. Mendenhall**, former consultant and liaison official with AAF. He will have headquarters at Teheran.

Edmund A. Laport becomes staff engineer for international communications systems and special apparatus at RCA Victor Div., Radio Corp. of America, Camden, N. J. His former position of chief engineer for engineering products at Canadian RCA Victor Ltd. is filled by **James B. Knox**, previously senior engineer.

For distinguished service in the application of electricity to air-



ELCO WOULD CONTINUE

to produce and deliver promptly

PRECISION wire-wound RESISTORS!

ELCO, too, awaits the go-ahead signal to start producing those "battle-tested" resistors for America's new Electronic industries.

Whatever the application—no matter how exacting the specifications—ELCO will deliver resistors as you want them—when you want them.

FOR TODAY'S WAR REQUIREMENTS—
FOR TOMORROW'S PEACE NEEDS—
specify ELCO!

SPECIFICATIONS:

"A-1"—15/32 long x ½" dia.—Mountable with 6-32 flat or filester screw. No. 21 tinned copper wire leads. 1 to 300,000 ohm value—½% standard accuracy—non inductive pie wound—½ watt. 30° C. temperature rise in free air—100° C. maximum operating temperature—200 D. C. maximum operating voltage. Baked varnish finish.

"A-R"—Same as A-1, with leads reversed.

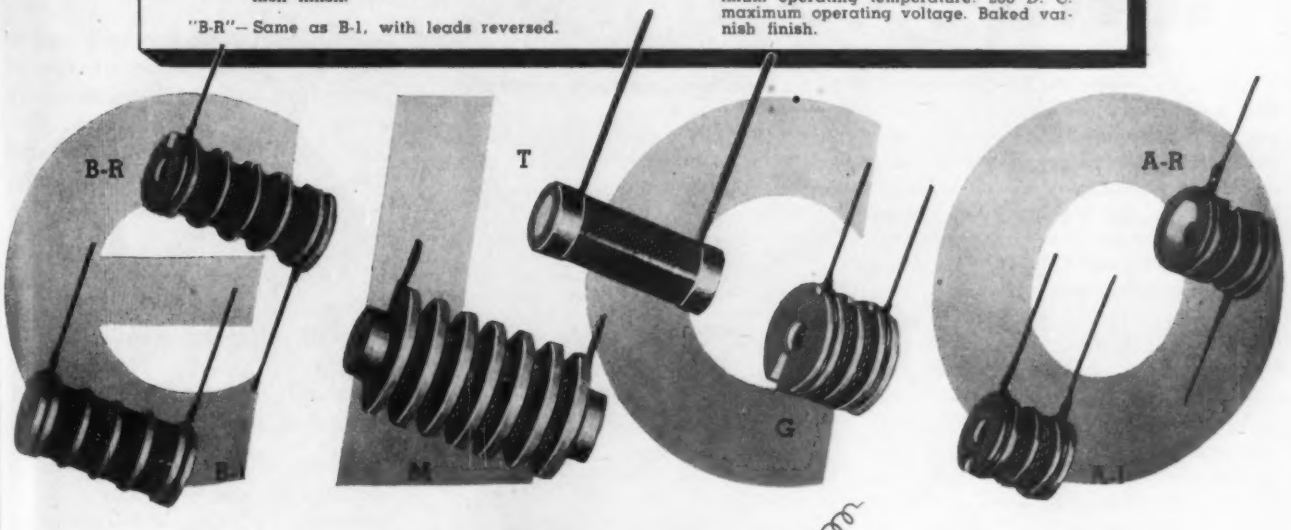
"B-1"—15/16 long x ½" dia.—Mountable with 6-32 flat or filester screw. No. 21 tinned copper wire leads. 1 to 500,000 ohm value—½% standard accuracy—non inductive pie wound—1 watt, 30° C. temperature rise in free air—100° C. maximum operating temperature—300 D. C. maximum operating voltage. Baked varnish finish.

"B-R"—Same as B-1, with leads reversed.

"T"—1-1/32 long x 7/16" dia.—Inductively wound—⅛ x .015 strap terminals—35 to 35,000 ohms—2 watts. 100° C. maximum operating temperature—normal accuracy 1%. Baked varnish finish.

"M"—1-13/32 long x ¼" dia.—Mountable with 6-32 screw—⅛ x .015 thick strap terminals—non inductive wound—1 meg ohm maximum resistance—600 volts maximum operating voltage—100° C. maximum operating temperature—1.5 watts—1% normal accuracy Baked varnish finish.

"G"—15/32 long x ½" dia.—Mountable with 6-32 flat or filester head screw. No. 21 tinned copper wire leads. 1 to 500,000 ohm value. ½% standard accuracy—non inductive pie wound .8 watts. 30° temperature rise in free air. 100° C. maximum operating temperature. 200 D. C. maximum operating voltage. Baked varnish finish.



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RESISTORS COMPANY

114 West 18th Street, New York, N. Y.

Telephone - Watkins 9-4774-5

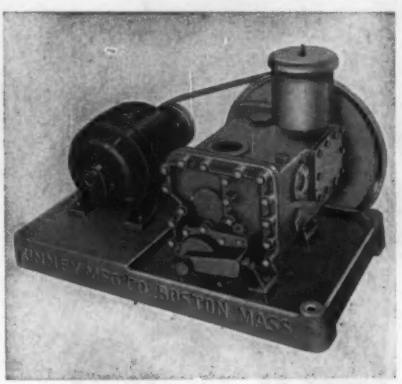
If you need plenty of Nothing

KINNEY VACUUM PUMPS

KINNEY Compound Dry Vacuum Pumps do a hand-painted job in creating and maintaining low absolute pressures down to half a micron (0.0000097 lbs. per sq. in. absolute)! This reliable performance speeds production and reduces the percentage of rejections in the manufacture of lamps, tubes and other electronic products. Where the pump is working on a new lamp or tube every few seconds, the high recovery speed and exceptional ultimate vacuum produced make KINNEY Pumps the choice of leading tube manufacturers.

Thoroughly tested in years of service, KINNEY Compound Dry Vacuum Pumps produce extremely low pressures year after year.

For the next higher range of absolute pressures, KINNEY Single Stage Vacuum Pumps are available in 8 sizes, designed to work at absolute pressures down to 10 microns.



Write for Bulletin 18

We also manufacture Vacuum Tight Valves, Liquid Pumps, Clutches and Bituminous Distributors.

KINNEY MANUFACTURING CO.
3565 Washington St., Boston 30, Mass.

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES SAN FRANCISCO

craft, **Richard E. Stowe, manager** of the Dayton, Ohio, office, **is given** the Order of Merit by his company, Westinghouse Electric & Mfg.

From International Resistance Corp., where he was vice president and works manager, **Leslie G.**

Thomas goes to Bayonne, N. J., to be works manager of Solar Mfg. Corp.

John J. Farrell is appointed engineer of the transmitter division in the electronic department of General Electric Co., Schenectady, N. Y. He used to be designing engineer for the division.

Vice president and chief engineer of newly-formed Madison Electrical Products Corp., Madison, N. J., is **John G. Ruckelshaus,** who has been doing development work for the Signal Corps. Plant supervision goes to **A. L. Livera,** previously assistant chief engineer at Hardwick-Hindle Co.

John B. Huarisa becomes executive vice president in charge of production and engineering for all divisions of Admiral Corp. Chicago, Ill. Vice president in charge of the radio division is former midwest manager, **Richard A. Graver.**

From the WPB office of civilian requirements, **Charles L. Saunders** goes to Wheelco Instruments Co. to be vice president. He was previously with Minneapolis-Honeywell Regulator Co. in a corresponding post.

Elections of new chairmen in the divisions of RMA include: **E. A. Nicholas** of Farnsworth Television & Radio Corp. to replace **R. C. Cosgrove** in the set division; **David T. Schultz** of Raytheon Mfg. Co. to replace **M. F. Balcom** in the tube division; and **C. J. Burnside** of Westinghouse to replace **George W. Henyan** in the transmitter division.

A PRECISION LABORATORY INSTRUMENT

FEDERAL

U. H. F. SIGNAL GENERATOR MODELS 804-CS1

also 804-CS2

FOR MORE DETAILED INFORMATION WRITE TO DEPT. E-9

PRICE
$350.00
F.O.B. FACTORY

Carefully and difficultly acquired experience enabled ***Federal*** to produce more Ultra High Frequency Test Signal Generators than were ever thought possible—and quickly, too.

Breaking the tightness of demand by the Army and Navy, these high quality laboratory precision instruments are available to research laboratories and industrial manufacturers engaged in the production of electronic equipment.

Your inquiries are invited.

CARRIER FREQUENCY RANGE: 7.6 to 330 megacycles plus or minus 2%, direct-reading in 5 bands, 6th band available for use with blank coil form supplied.

OUTPUT VOLTAGE RANGE: Calibrated Attenuator continuously variable from 1 to 20,000 microvolts, accuracy plus or minus 10%.

MODULATION: Internal Modulation 1,000 cycles; external modulation up to 20,000 cycles; 0 to 60% direct-reading modulation meter.

STRAY FIELD LEAKAGE: Held to a minimum by improved shielding and R.F. Filters.

VIDEO OR PULSE MODULATION: Can be pulse modulated externally with signals having very steep wave fronts.

VOLTAGE REGULATED POWER SUPPLY: 115 or 230 volts, 40 to 60 cycles, single-phase.

Manufactured by arrangement with the General Radio Company of Cambridge, Massachusetts, and in accordance with their designs.

ARMY E NAVY

FOR THE FOURTH TIME

BACK THE INVASION . . . KEEP BUYING MORE WAR BONDS

Federal Manufacturing and Engineering Corp.

Manufacturers of Federal Photographic Equipment and Federal Electronic Devices

BROOKLYN 5 NEW YORK

HARDWICK, HINDLE PRODUCTS ARE SUBJECT TO HIGH PRIORITY RATINGS

Like many other fine products, they are subject also to first call by Uncle Sam.

We are proud of the service they are performing in so many defense jobs.

HARDWICK, HINDLE, INC.
RHEOSTATS and RESISTORS
DIVISION OF
THE NATIONAL LOCK WASHER COMPANY
ESTABLISHED 1886
Newark 5, N. J., U. S. A.

Broadcast Relay System

(*Continued from page 97*)

future units will be equipped with a readily removable loudspeaker unit and an additional volume-indicator meter. This extension unit could then be mounted at a point somewhat remote from the transmitter and convenient to the operator where he could control the level of the monitor speaker or switch over to the meter alone if answering the telephone, handling telegrams or conducting other business.

The twelve units now in operation have exceeded expectations in regard to coverage and very little time has been lost due to tube and equipment failure. When the suggested conversions have been made the time lost due to equipment and tube failures will be further reduced and should not exceed two to three hours per unit per year.

The idea of serving remote listeners by means of a number of small transmitters was originally conceived by the CBC's chief engineer, Mr. G. W. Olive. Co-operating with the author in the development of the project were Messrs. J. A. Ouimet, H. M. Smith, W. G. Richardson and R. D. Cahoon of the CBC's Engineering Division.

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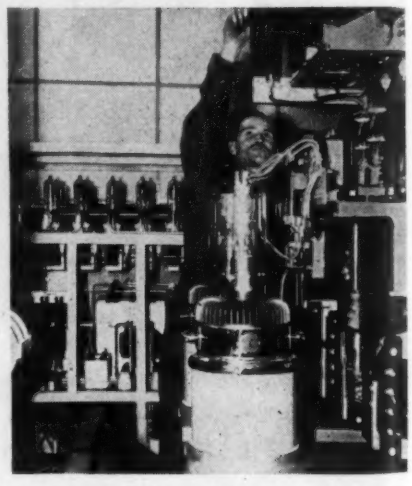
BRITISH COMMUNICATIONS



Shown above is a new station of Royal Signals, the British Army unit that provides radio communication between the War Office and war theaters. The operating staff is located in London and the transmitters are keyed by audio tone signals over land lines to the stations

For mobile two-way communication specify KAAR RADIOTELEPHONES

KAAR PTL-10X TRANSMITTER

10 WATTS • 1600-2900 KC*

The PTL-10X is a highly efficient medium-frequency mobile transmitter. It provides communication from a moving vehicle over distances ranging from 50 to 75 miles when used with AUTO-LOAD self-loading antenna.

The "Push-to-Talk" button on the microphone completely controls the transmitter, lighting the instant heating tubes, starting the power supply, automatically silencing the receiver, and switching the antenna to the transmitter. The standby current is zero.

Models for special applications are available, including the PTL-22X medium frequency transmitter with 22 watts output, and the PTS-22X, a 22 watt transmitter for operation in the 30-40 MC band.

KAAR 11X RECEIVER

6 TUBES • 1600-2900 KC*

The popular 11X receiver is a crystal controlled superheterodyne for mounting in an automobile or other vehicle. It contains a no-signal squelch circuit, and is designed for commercial, civil, and military applications.

This receiver offers remarkable accessibility. The top is removed by simply pushing aside two snap catches, or the entire receiver can be whisked out of the vehicle by releasing only four catches.

KAAR AUTO-LOAD ANTENNA

This antenna, with matching coil in the base, is designed for use with the PTL-10X (or with similar medium frequency transmitting equipment) and matches the 72 ohm transmission line from the transmitter and receiver without auxiliary tuning equipment. It provides an efficient method of obtaining maximum signal strength at medium frequencies with a short antenna. It can be quickly installed on the rear bumper or on the side of any vehicle.

**Special ranges to 7000 KC available on special order*

KAAR

ENGINEERING CO.

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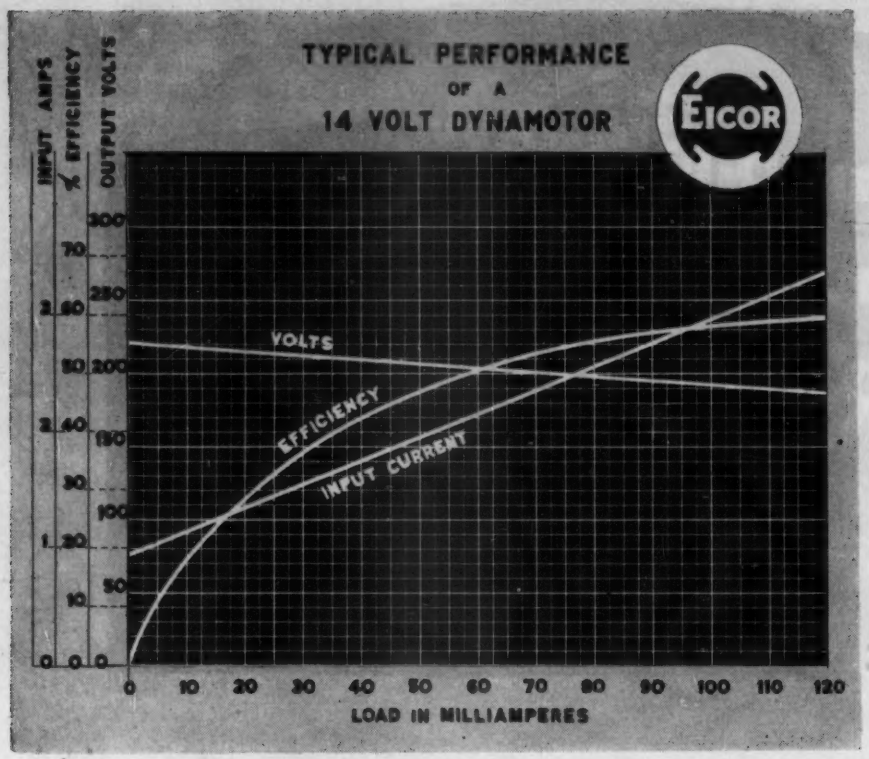
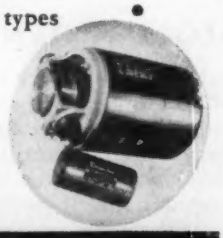


CARDIOGRAPH

The diagnosis of a healthy dynamotor furnishes the data for proving or improving the fine points of performance. Beginning with laboratory development, and through the various stages of production, performance analysis shows our engineers just how closely design and actual functioning are coordinated to meet precise specifications.

The performance curves we supply the many organizations using Eicor products play an important part in establishing dynamotor requirements. In the field of electronics, engineers find these charts extremely useful in determining such factors as efficiency and voltage regulation at the various points of power output which are characteristic of a given design. With operating details of their electronic apparatus established, this graphic presentation of performance shows how the dynamotor is affected by varying conditions of load. Illustrated are the performance characteristics of an exceptionally compact permanent magnet field 14 volt dynamotor, rectangular in shape.

Eicor manufactures many types of dynamotors, motors, and like equipment. In each design, our performance tests are considered complete only after months or years of actual service have proved the quality of the units. That's another reason why Eicor products are so frequently specified.



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Generator of Microwaves

(*Continued from page* 115)

on the transplantable sarcoma of the mouse.

Out of a total of 43 white mice of mixed strain, inoculated with A. 80., 28 mice were treated against 15 kept as control. The mice were irradiated on the whole body as they moved freely inside a jar positioned under the radiant unit. Out of the 28, 18 mice recovered, indicating after the third application of the rays a reduced activity with increasing hardness and dryness of the sarcoma, which at the end always fell from the body of the mouse as an ordinary scab. The balance of 10 mice died.

Interesting is the fact that the dessication occurred without any apparent thermal effect outside or inside the mouse's body. Out of the 15 control mice, 13 died and 2 recovered although, in the latter ones, the tumor, growing smaller and smaller, continued to remain soft and active until reabsorbed. Due to the war emergency in June, 1941 the experiments had to be discontinued.

The author wants to thank Dr. Walter Toscanini and his friends who financed the construction of the apparatus; Dr. Lenz, former Chief of the Division of Cancer, New York City, who supplied the mice and the laboratory facilities; Dr. DeGregorio, also formerly with the Cancer Division, for his continuous interest and presence during the performance of the experiments and Prof. W. C. Ballard, Jr., of Cornell University who revised the present paper.

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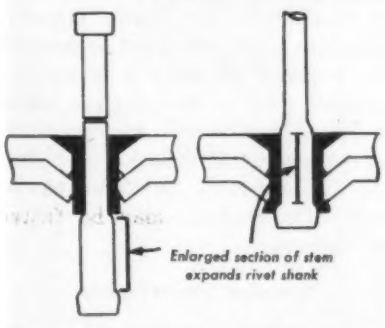

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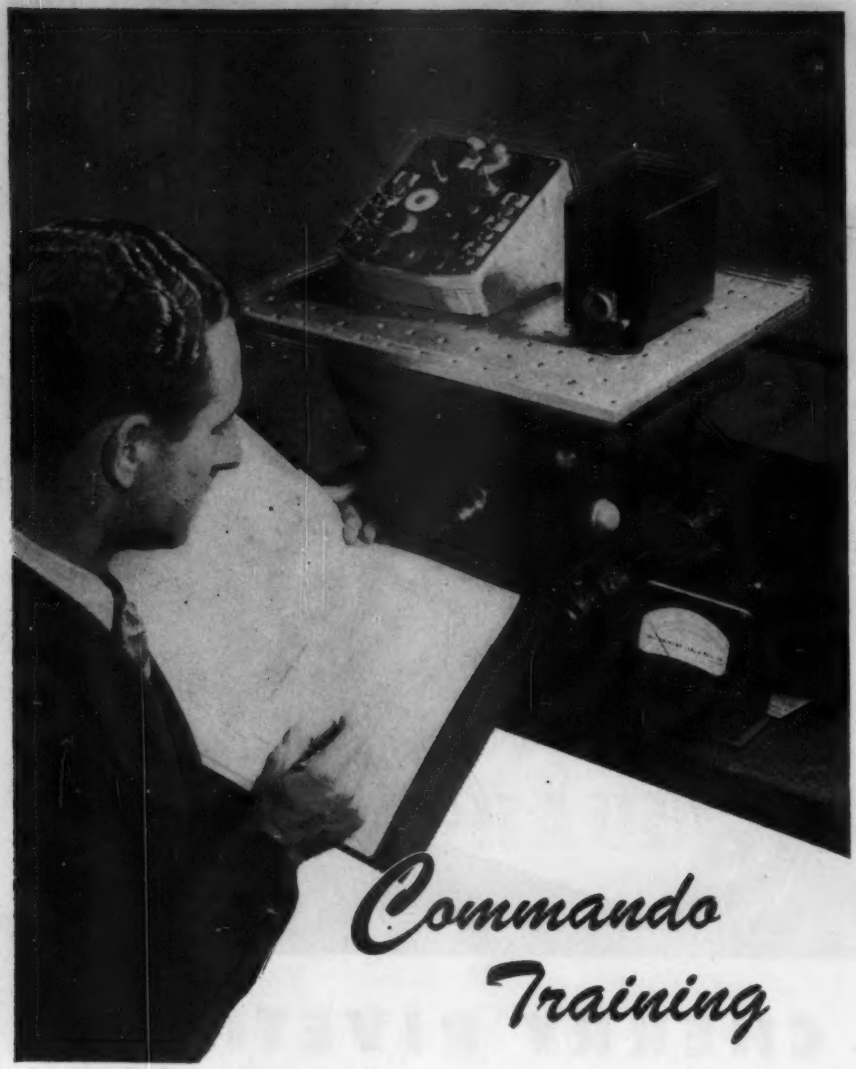

DELICATE radio devices are receiving rigid, commando conditioning at Pacific Division's Radio Development Laboratory. This equipment, too, must be ready to take terrific punishment under the worst fighting conditions. To make dead sure that it can take it, radio apparatus is subjected to long gruelling tests on powerful vibrating machines which simulate actual airplane engines flying at top speed. Only until it can complete these conditioning courses with colors flying, is this equipment ready for "combat duty".

This attention to detail in perfecting lightweight, durable and reliable radio equipment has been the aim of the Radio Laboratory's engineers, and the products they have developed are distinguishing themselves under fire as notably as the men who rely on them.

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Petroleum Research

(*Continued from page* 140)

recently it has been shown that if styrene or conjugated diolefins are removed, the analysis can be made on the total octane cut (250–295 deg F).

Absorptions in this wavelength region are caused by electronic transitions related to the resonating groups within the molecule. In aromatic compounds with aliphatic side chains these resonating groups are in the nucleus or ring portion of the molecule. Thus, altering the position of the side chain on the ring (o-, m- and p-xylenes) or adding side chains (toluene is benzene plus a methyl group) usually causes a marked difference in the ultraviolet absorption spectrum. But increasing the length of the side chain has less effect upon the spectrum.

For analysis, a weighted quantity of sample is diluted with a non-absorbing solvent such as isooctane and placed in an absorption cell with quartz windows. Ultraviolet light, preferably from a continuous source such as a hydrogen lamp, is passed through the sample cell, dispersed by a quartz prism, and the resulting spectrum examined to determine regions of absorption.[18]

The spectrum may be photographed, but small ultraviolet monochromators are available which detect and measure the spectrum by means of phototubes. These are preferred for routine analysis for several reasons. First, photography and all its accompanying equipment and trouble is eliminated. The phototubes measure the intensity of the ultraviolet light directly. Secondly, once a method is devised for a given analysis, it is usually not necessary to examine the whole spectrum but merely necessary to measure the transmission at a few specific wavelengths. The photoelectric instrument may be faster in such cases.

Emission Spectroscopy

The region from about 10 to 2,000 Angstroms in the electromagnetic spectrum is not of industrial importance at present largely because of experimental difficulties. In this region air, quartz, and even

History of Communications Number Seven of a Series

EARLY COMMUNICATIONS BY AIR

While electronics use the ether and other media, one of the most speedy methods of communications in the early days was through the air by carrier pigeon. With a finely printed note fastened to the leg, these birds faithfully reached home to bring in the latest news events and stock market reports.

Today news commentary reaches into your homes in a flash of a second via electronic voice communications making use of the various types of Universal broadcast microphones. This being a modern age, the battle front is brought into the homes of the informed peoples of the democracies via military microphones such as those now being manufactured by Universal for the Allied Armed Forces.

< Model 1700-UB, illustrated at left, is but one of several military type microphones now available to priority users through local radio jobbers.

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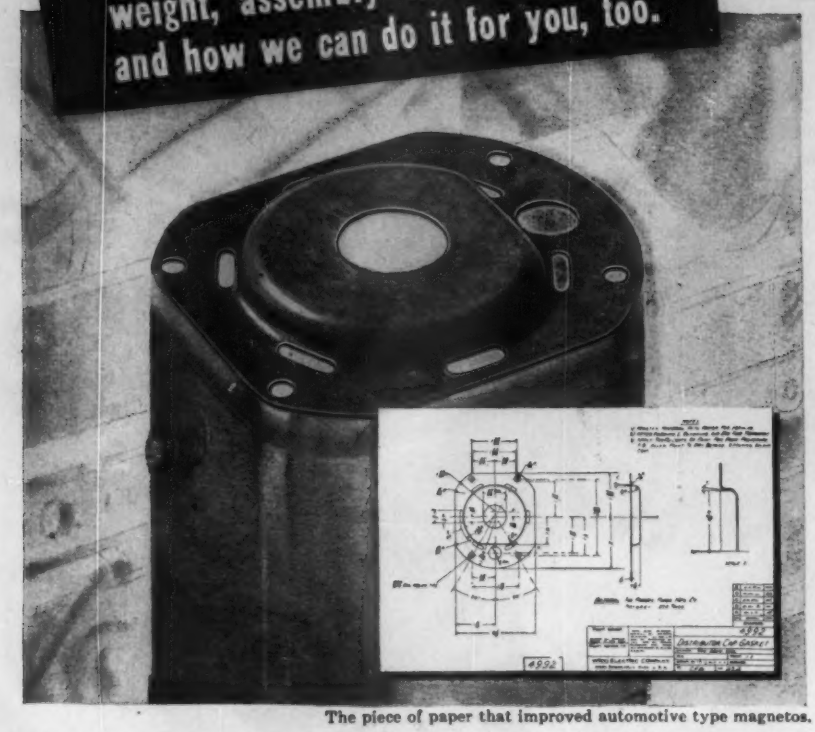

The piece of paper that improved automotive type magnetos.

Engineers at Wico Electric Company, West Springfield, Mass., conceived this ingenious part to replace a gasket and a metal dustcover on one of their automotive type magnetos. Insulating properties of the material* eliminate arcing, it is lighter than the metal replaced, and it is readily formed and punched in two fabricating steps, resulting in an accurate, tough, one-piece component for quick assembly.

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*Material in this case was Rogers .020" KAYGREY, one of many Rogers wet-process, laminated cellulose sheet products. Made of new cotton fibers and chemically purified wood pulp (50% of each), its properties include:

	Typical Test Values
Specific Gravity	1.35
Tensile, parallel grain—p.s.i.	14,550
Tensile, cross grain—p.s.i.	5,450
Elongation, parallel grain—%	7.8
Elongation, cross grain—%	11
Mullen, lbs.	535
Dielectric—VPM	532
Tear, parallel grain—gms.	1,239
Tear, cross grain—gms.	1,940
pH	7.0

If you should be planning a new material, Rogers can, with a total of 25 lbs. of all materials involved, produce within 48 hours a sample that will duplicate regular production runs, and can test all properties. This is possible with glass fibers, leather, asphalt, asbestos, lignin, rubber, phenolics, ureas, cork, vinsol or any other materials that will go through a water process and a paper machine.

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the gelatin in photographic plates absorbs the radiation. However, the spectrum from 2,000 Angstroms through the visible region (roughly 4,000 to 8,000 A) up to 12,000 Angstroms can be recorded on photographic plates. Many years ago, phenomena observed in this region formed the basis for the interpretation of modern atomic theory.

Everyone is familiar with the rainbow. This visible spectrum (the separation of white light into its component colors), which in the case of the rainbow is produced by water droplets in the sky, is more readily produced in the laboratory by means of prisms or finely ruled gratings. The spectrum also contains light invisible to the eye.

One commercial emission spectrograph, in use in the Socony-Vacuum laboratories, uses a prism to separate the ultraviolet, visible and near infrared (2,000 to 10,000 A) into component wavelengths. The prism used most frequently is of quartz and gives high dispersion (wavelength separation) in the ultraviolet. A glass prism may be substituted for the quartz to increase the dispersion in the visible and near-infrared regions. Some investigators prefer instruments which use finely ruled gratings as the diffracting medium. The dispersion of grating instruments does not vary with wavelength.

If an unknown sample is burned and the light given off analyzed by a spectrograph, the elements present in the sample can be determined. Under proper conditions, atoms of any element will emit characteristic light. Such light is emitted when the outer electrons of an atom are disturbed or made to change energy levels. The metallic and metalloid elements can be readily excited by thermal energy supplied by a flame, arc, or spark. The nonmetallic elements are more difficult to excite. Spectra or characteristic light of the non-metals is usually excited by ionization in a gaseous discharge.

Industrially, then, emission spectrography is primarily useful for the exact and infallible identification of the metals and metalloids (phosphorus, arsenic, antimony and bismuth). It is especially useful in the determination of these elements where they may be present in very low concentrations. Most of

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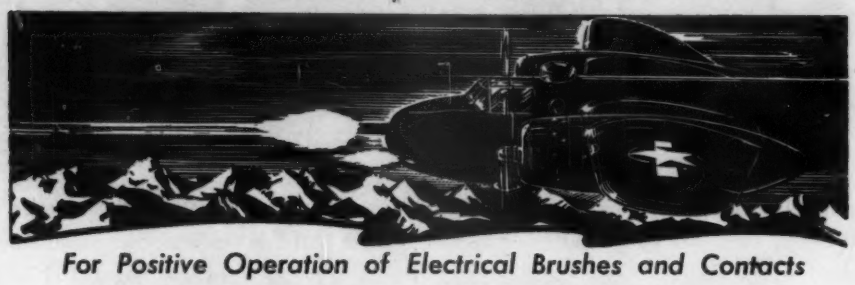

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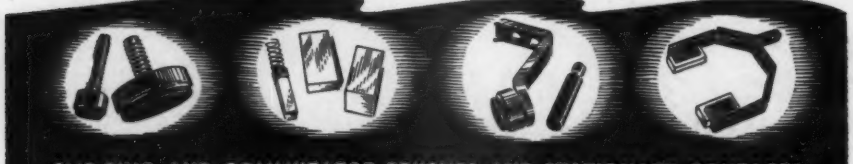

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the metallic elements can be positively and readily detected when present at only a few parts per million of the total sample. Elements which are difficult to identify uniquely by chemical means, as for example the alkali elements, are easily distinguished spectographically. It has been stated that no metal has ever been made so pure that the spectrograph could not find impurities present.

Quantitative analyses for the metals and metalloids can be made by spectrographic methods[34, 35, 36]. The sample is burned, the spectrum recorded, and the photograph developed under rigorously controlled conditions. The optical density of chosen lines is measured on a microphotometer and compared with those from known samples of approximately the same composition.

To summarize, if samples are of a kind that must be burned in a direct-current arc, then the quantitative accuracy will probably not exceed ± 10 percent of the amount of the element present. For example, if magnesium were present in a clay catalyst at 10 percent, spectrographic methods would report it as 10 ± 1 percent at best. However, if it were present at 0.01 percent it might be reported as 0.010 ± 0.001 percent.

Quantitative spectrographic methods are especially useful to determine metallic elements in low concentration, where the accuracy of the spectrographic method usually exceeds other analytical methods. If a large number of analyses of a given kind are to be made, then spectrographic methods are rapid and time saving.

Certain metallurgical analyses are made spectrographically wherein the sample is burned in a carefully controlled spark source. The analytical results often equal, or are better than, those obtained by wet chemical methods and the time saved by the spectrographic method is almost unbelievable. Alloy steels have been analyzed to determine the concentration of some six elements and the results reported within a quarter of an hour after the sample is received.

X-Ray Diffraction

X-ray diffraction provides a means for the unique identification of crystalline materials. Just as a

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THIS unretouched photomicrograph, approximately 50 times actual size, shows pretty clearly what we mean by the value of experience, when it comes to the making of electrical instruments and testing equipment.

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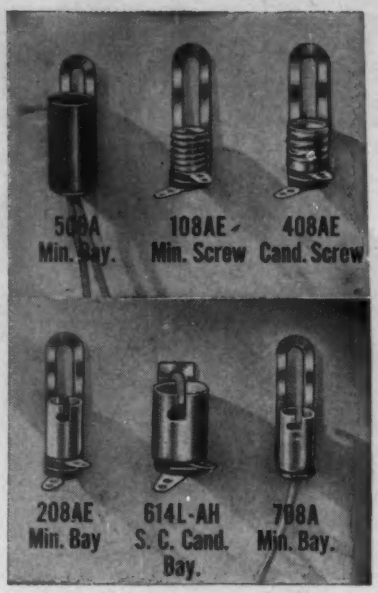

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human fingerprint serves to identify a particular person, an x-ray diffraction pattern is a fingerprint of a crystalline material. This is possible because the distance between the atomic building blocks in crystalline materials is of the same order of magnitude as the distance between wave crests in an x-ray beam. Thus the atomic building blocks can act as diffraction centers and the crystalline material as a diffraction grating for an x-ray beam.

Specific examples of the use of x-ray diffraction in a petroleum laboratory include the identification of inorganic deposits found on valves, bearings, oil filters and other engine parts. Approximately 95 percent of the inorganic materials encountered will yield an x-ray diffraction pattern by means of which it may be possible to identify them. Other industries find the x-ray method extremely valuable in determining the structure of metals and alloys.

Electron Diffraction

The electron diffraction method as applied to industrial petroleum problems is very similar to the x-ray diffraction method. As the name implies, electron waves are diffracted rather than x-rays. Electron waves are slightly shorter in wavelength than x-rays but, unlike electromagnetic radiation of similar wavelength, electron waves do not have the intense penetrating power of x-rays or gamma rays. Electron diffraction supplements x-ray diffraction when it is desired to study surface phenomena which may be too thin to be detected by means of x-ray diffraction.

Electron Microscopy

In the past several years electron microscopes have become available which make it possible to see objects far smaller than can be resolved in ordinary microscopy. In electron micrography, electron waves travel similarly to light rays in an ordinary microscope except that in place of glass or quartz lenses the electron microscope substitutes electrostatic or magnetic fields. The maximum resolution possible at present probably does not exceed 0.01 microns (0.000,001 cm or 100 A). However, another feature of the electron microscope

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which is very important is the remarkable depth of focus found in electron micrographs, which thus reveal more detail than could be seen heretofore under similar magnification by other methods.

X-Ray Microradiography

A relatively little known but potentially useful technique is that of x-ray microradiography. Microradiographs of thin sections of any material may be obtained using techniques similar to that of inspecting castings, welds, etc. except that the specimen is very thin and the film is capable of extreme enlargement. The pictures obtained are truly microradiographs, for the original is usually ½ inch or less in diameter and sections of this are then enlarged about 300 times.

This microradiographic technique supplements the optical microscope in metallurgical and other industrial applications, with several advantages; it gives a three-dimensional view of the specimen; does not depend on differential action of etchants but only on the variations in absorbing power of constituents, including internal voids and cracks; requires no special polishing of the specimen; and can be incontrovertibly interpreted. The

• • •

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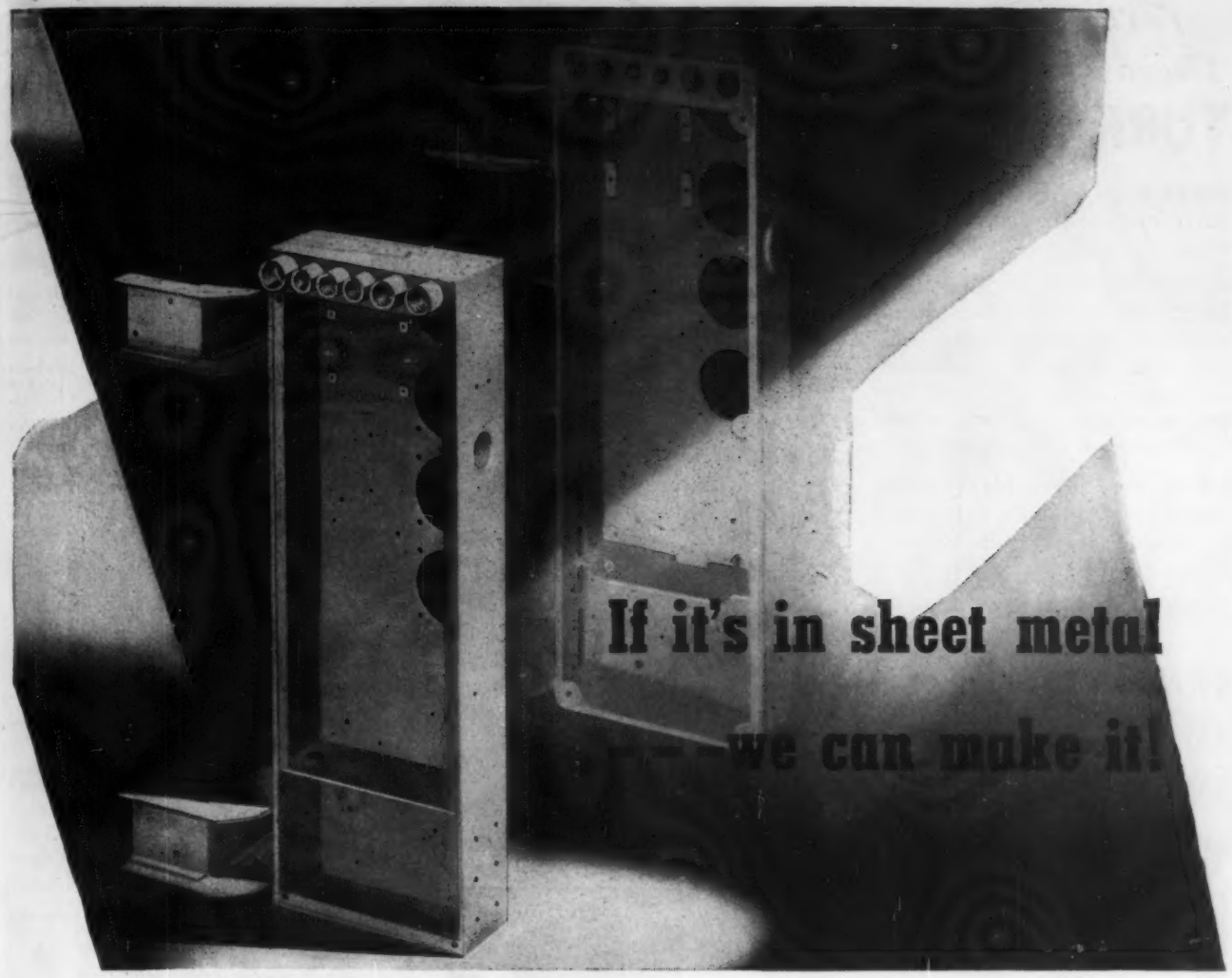

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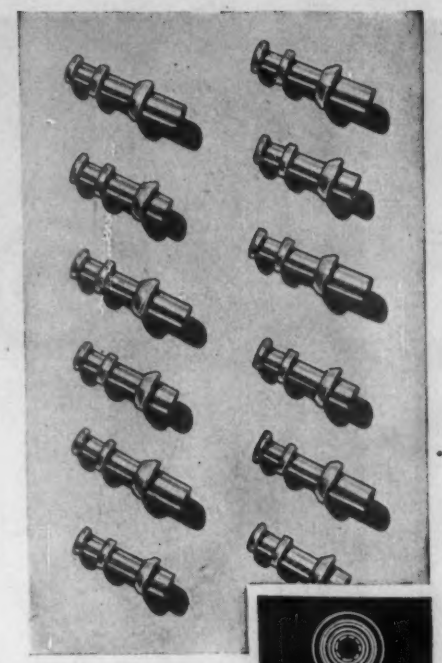

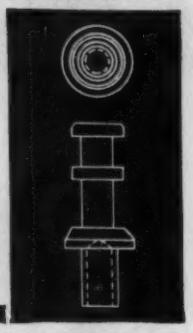

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major difficulty lies in obtaining a specimen section 0.010 inch or less in thickness from the material to be inspected.

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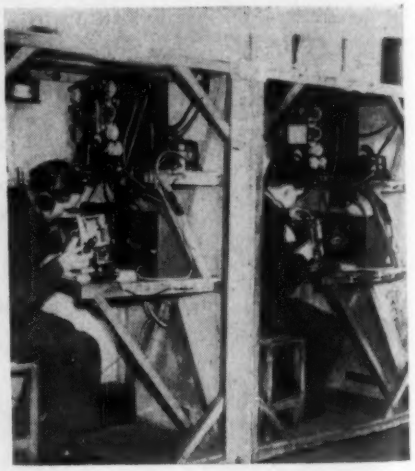

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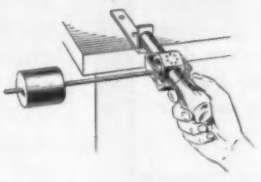

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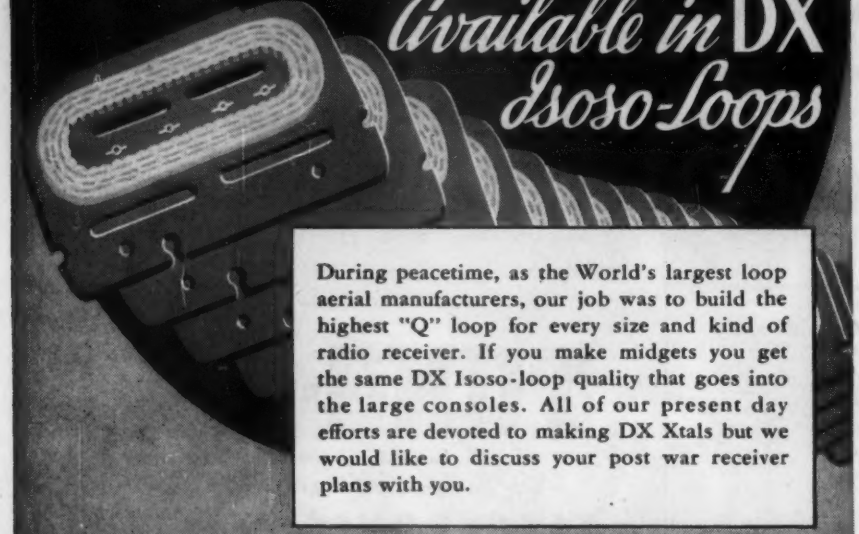

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Vacuum Capacitors

(*Continued from page* 127)

air device, with a low-frequency capacitance of 100 $\mu\mu$f may exhibit a rise in effective capacitance of about 30 percent at 50 Mc.[1] For a given capacitance and voltage rating, a vacuum capacitor is much smaller in size than an air unit and has far less self-inductance. Therefore, its net change of capacitance with frequency—even at very high frequencies—is very slight.

Effects of humidity and fungus growths are critical in tropical regions. Plates of variable air capacitors often require daily cleaning for removal of corrosion and fungus both of which can cause transmitter failure. Some types of fungi secrete a corrosive fluid which not only attacks metal, but also unglazed ceramics and most other types of insulating materials. The vacuum capacitor may eventually find wide application in tropical climates because it requires a minimum of maintenance.

Vacuum Capacitor Applications

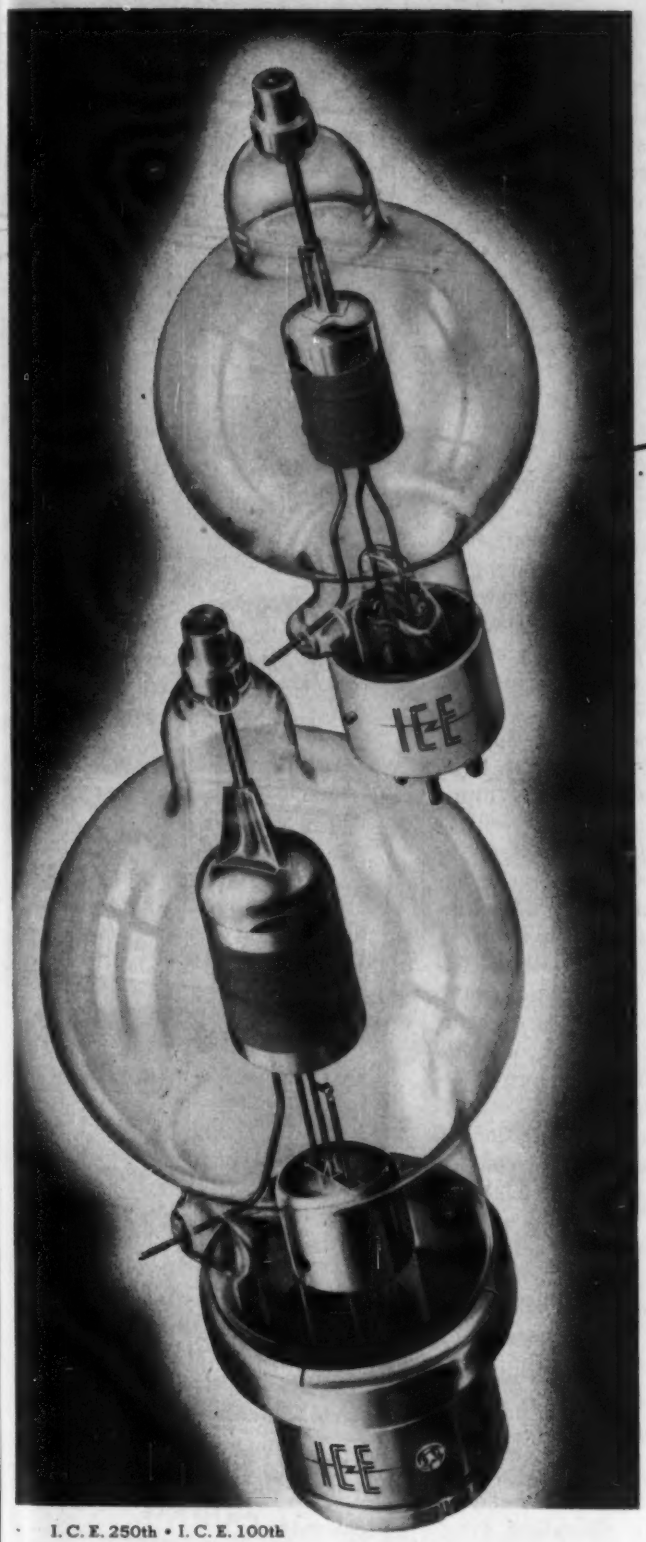
Vacuum capacitors are particularly suitable for transmitter tank applications where high voltages are involved and where space is at a premium. Resonant frequency of the tank circuit can be varied in the inductive component.

Where a short transmitting antenna is used at medium or high power input, the vacuum capacitor can be employed to good advantage for antenna coupling, because of the unusually large rf potential developed. Series-parallel combinations make up an unusually compact, stable capacitor bank where high potentials are involved.

In aircraft equipment, vibration-proof construction, small size and stable voltage ratings are a considerable asset. This type of capacitor may also be of value in uhf installations where precise, unchanging capacitance is essential. They may find further application in many kinds of precision apparatus, in which frequency stability is particularly important.

Pressurizing With Gas

Gas-filled capacitors, feature high voltage ratings by utilizing



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certain desirable properties of gas dielectrics.

Where an electrostatic field exists between two electrodes in a gas, the voltage gradients are not distributed evenly. There is no constant proportion between current and field strength, as in metals. Therefore, a gas is not referred to as having resistance. The discharge of electricity in gases is extremely complex, and is dependent on many factors, one of these being density of the gas.

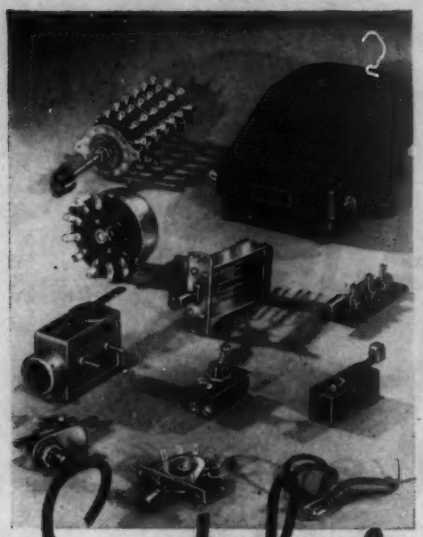
Referring back to Fig. 1, we find that after the pressure is raised above minimum sparking potential of any given gas, for a given electrode spacing, the sparkover voltage increases in approximate proportion to the pressure. Pressures of the order of 350 lb per sq in. will decrease the mean free electron path to a great extent, as demonstrated by Fig. 3, so that an electron moving from one plate toward the other would undergo a huge number of collisions. This minimizes the tendency toward ionization. Field strength necessary to produce an electrical discharge becomes proportionately high, imparting to the pressure capacitor a large flashover rating. Other features are rugged construction, very low losses, low temperature coefficient, stable dielectric constant, variable capacitance, and provision for external flash-over.

Rigid mechanical construction of the pressure capacitor is a considerable asset. The gas-filled chamber is usually of aluminum or copper-plated steel while the actual capacitor elements have sturdy, precision-made plates, with edges accurately rounded to increase breakdown potential and eliminate corona.

Variable Models

Some models are of the variable type, where the capacitance can be changed while in operation from about 40 percent to maximum rating. The rotor shaft is brought out through special pressure seals. A worm gear is utilized to give ratios from 15-to-1 up to 900-to-1. These units can be supplied with motor-driven remote control, including automatic stops, so that pressing a button provides a quick and accurate change of value.

Fixed units can be set at the fac-



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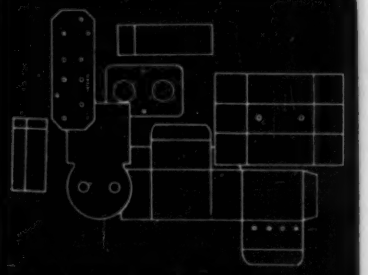

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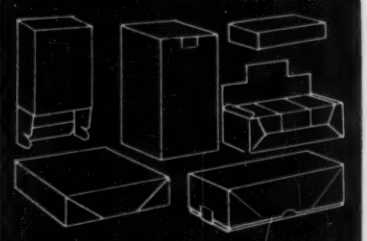

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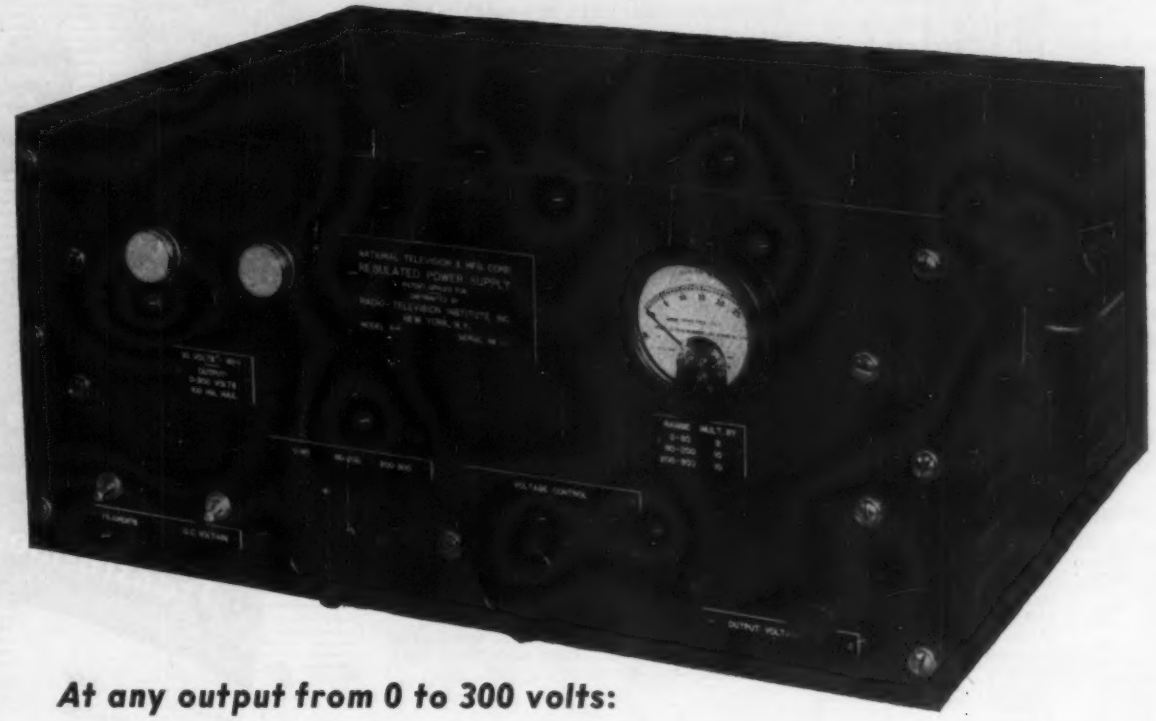

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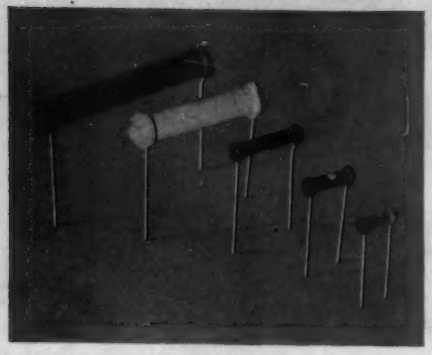

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763-A	1/4	47 Ohms to 15 Megohms	5/8"	7/32"
759-A	1/2	33 Ohms to 15 Megohms	3/4"	1/4"
766-A	1	47 Ohms to 15 Megohms	1 1/8"	1/4"
792-A	3	22 Ohms to 150,000 Ohms	1 7/8"	15/32"
774-A	5	33 Ohms to 220,000 Ohms	2 5/8"	15/32"

TYPE "CX" RESISTORS

997-CX	1/4	1 to 150 Ohms	21/64"	7/64"
763-CX	1/2	1 to 47 Ohms	5/8"	7/32"
759-CX	1	1 to 33 Ohms	3/4"	1/4"
766-CX	2	1 to 47 Ohms	1 1/8"	1/4"
792-CX	4	1 to 22 Ohms	1 7/8"	15/32"
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Pressure capacitors are used in broadcast and similar r-f applications. They are employed in high-voltage tank circuits, and are also used for neutralizing or coupling. Pressure capacitors are suitable for use in both d-c and a-c applications. Within the past few years, considerable progress has been made in the design of these capacitors, making possible higher voltage and higher frequency applications.

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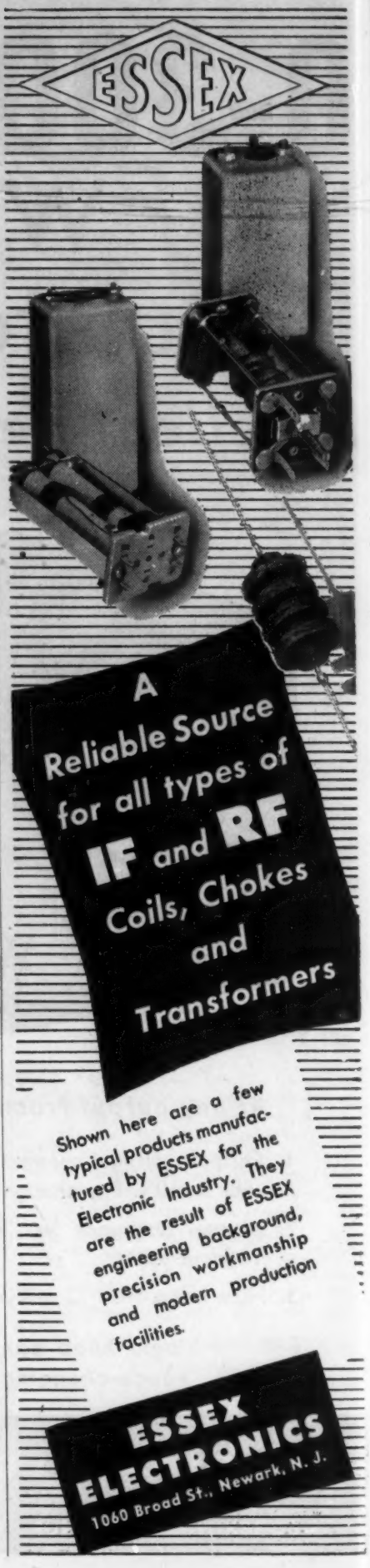
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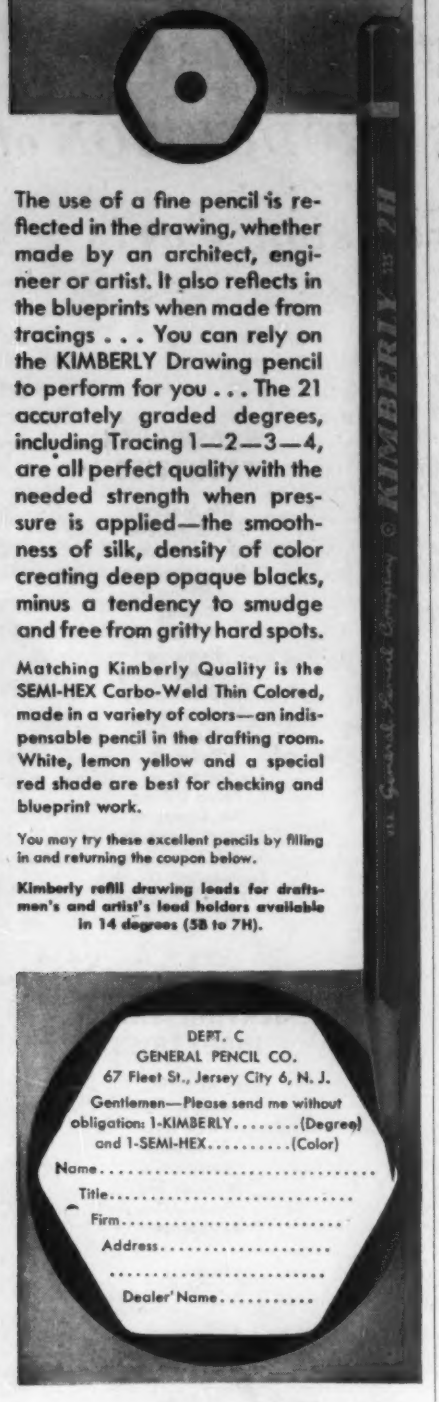

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Impedance Measurements

(*Continued from page* 140)

transformer can be placed ahead of the oscilloscope, presenting to the test circuit merely the grid loading of a vacuum tube (Fig. 1).

With the input and output impedance effects minimized, the only remaining limitation on the range of utility of this method is that of frequency. The percent deviation of the wave produced by the generator from an ideal square wave is the minimum percent error to which impedance measurements can be made. The amplitude and phase shift response of the oscilloscope must be linear from at least ten times the highest square-wave frequency at which tests are to be made, to one-tenth the lowest.

To determine the frequency range within which the equipment is reliable, the generator output should be observed on the oscilloscope to be used. This procedure does not indicate which of the instruments is at fault but, because distortion in either one is equally detrimental to accuracy, it does indicate the usable range for the combined equipment.

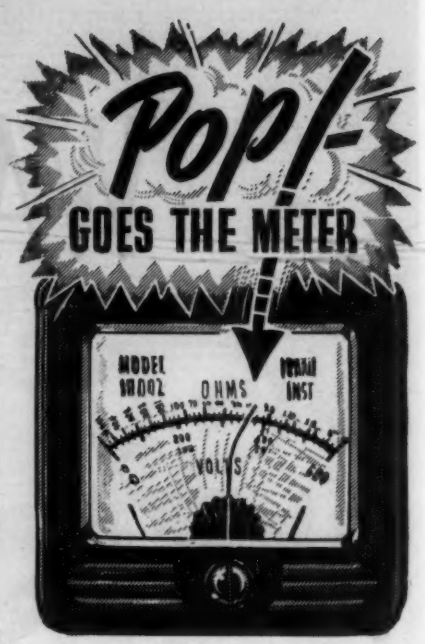
Stray shunt capacitances to ground must be kept small. Such strays are most likely to appear from the unknown impedance to surrounding metal such as the cases of the generator and oscilloscope. Even at moderately high frequencies, lead inductance distorts square waves and therefore it is necessary to hold all lead lengths to a minimum. Because of the wide

—◇—

A PASHA in North Africa has an intercommunicator system that permits him to contact each room in his harem when necessary. Interested in improvement, he asked Maj. Andre Baruch, former announcer now in Africa, "How is television progressing in your country, Major?"

—◇—

MORE THAN 150 new electronic tubes and 300 types of apparatus not made by anyone before the war have been developed by RCA for the armed forces.



What happened to your meter when you made a miscue and slammed the pointer against the stops? Does the pointer above revive unpleasant memories?

Until Supreme started production of its own meters, the best general purpose meters available were secured for our test equipment. They were good . . as good as any general purpose meter can possibly be Today, however, Supreme built meters are designed for one specific field . . . the electronic service man.

Think back over the past years. How many days and dollars have you lost because of a slammed meter? No meter is indestructible, but these Supreme Meters can take it. Accurate? Yes! And double-rugged!

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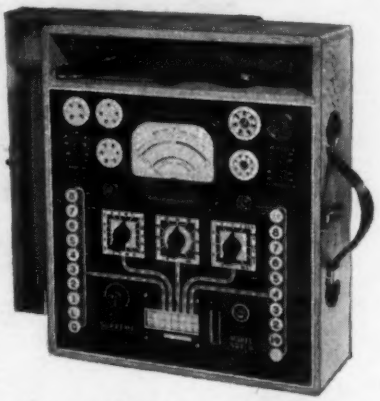

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DEAR SIRS. During a few quiet spare moments out here on the latest battle front, I thought that perhaps you would care to know the history of one of your model 8-K Recording Machines. Just what it has been through, just what it has done for thousands, perhaps millions of people all over the world, and just what it is doing at the present moment.

It was available in Cairo over two years ago, and the RAF purchased it for the Mobile Recording Unit for work on the front, recording everything and anything that would be interesting to the public of the world.

I am the engineer that has had the pleasure of operating this machine all this time, and being in the radio trade for fourteen years, should know when a set is well made or not.

It has travelled over 23,000 miles. Aproximatly 20,000 by road, track, or desert, in one of the hardest sprung trucks of the British Army, and 3,000 by air.

It has recorded bomb and shell explosion in slit trenches, covered with dust. Blown over on one occasion by blast.

Dropped on numerous occasions.

Has recorded in the air, and on sea rescue craft, with better results than expected.

2

Has travelled to:+ Amman Transjordan, to Tripoli, back to Cairo, back to Tripoli, on to Tunis, Bizerte, on to Algiers, back to Tunis, on to Sicily, all through Sicily, on to Italy. All this way by truck, recording, recording. recording. Never once, through all this bumping, buffetting, and banging about, has it let our little party down. Never in my opinion, has any radio apparatus stood up so well, for so long in such conditions.

Recordings from this machine have been broadcast from the following countries. England; America; Canada; New Zealand; Australia; Sth Africa; Egypt; Palestine; Algeria. Perhaps presently, from Italy itself.

Please thank your engineers and assembly workers for such an efficient and trouble free recorder, and may you continue to put such products on the market.

If you care to acknowledge this letter please address to my home in England. 110 Cardinal Avenue, Morden Park, Morden, Surrey. GB.

Yours truly,

B R Tinniswood

To:+ The Managing Director,
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frequency response of the oscilloscope, the circuit must be shielded from stray fields.

Typical measurements are illustrated in the following table which gives an indication of the accuracy to be expected from square-wave impedance measurements of this type.

ACCURACY OF CAPACITANCE MEASUREMENTS

Actual μfd	Measured μfd	Percent Error	Frequency cps
0.1000–	0.088	12	60*
0.0100–	0.0092	8	580
0.001(4)	0.0010(2)	(2)	5200

Calibrated resistor used in this measurement was 30,000 ohms.
*Generator output noticeably not a square wave at this frequency.

EFFECT OF IMPEDANCE ON INDUCTANCE MEASUREMENTS

Resistance Ohms	Frequency cps	Inductance mh
314	740	0.068
3140	3300	0.152
3140	3800	0.132*
31400	27000	0.185

*Internal impedance of the generator was 1000 ohms for this one measurement.

Test equipment used in these measurements was connected directly to the impedances under test (not as shown in Fig. 1) to illustrate the accuracies which can be expected if commercial equipment is used directly, and to show the desirability of using impedance-changing networks where higher accuracies are required. The internal impedance of the square wave generator was 500 ohms; the input impedance of the oscilloscope was 2 meg.

The value of R used in measuring capacitance was chosen as the mean between the generator and oscilloscope impedances $(500 \times 2 \times 10^6)^{\frac{1}{2}} = 33{,}000$ ohms. The constants of the inductor for which the measured values are given are: L, 0.189 mh; f_o, 48,000; Q, 11.8 at 1000 cps.

Measurements of this inductor could not be carried out using larger resistances because of the free oscillations appearing on the trace; the low resistances used damped these oscillations. The particular values of R used in measuring inductance were chosen to cancel the π term. Data is only reliable to three places in the above measurements.

REFERENCES

(1) Brailsford, H. D., Measuring Coil Characteristics Without an Impedance Bridge, ELECTRONICS, May 1943.
(2) Richter, Walther, Cathode Follower Circuits, ELECTRONICS, November 1943.

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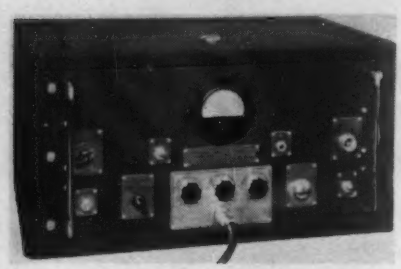


Lavoie Laboratories, Morganville, N. J.

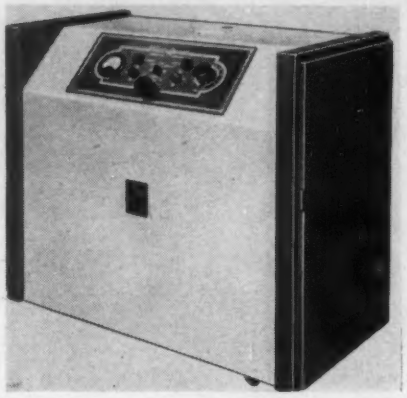
Time-Delay Relay

MODEL TD6 time-delay relay is intended for use in protecting industrial and transmitter tubes. It has a cam-operated switch mechanism and is mounted in a dust and moistureproof Bakelite case for panel mounting. A visible index shows the open and closed position by means of a graduated indicating-dial. Four screw-type terminals are included for motor and switch circuits. A totally enclosed switch unit is used in the relay. This switch has definite snap action and positive lock in both operating positions.

The R. W. Cramer Co., Inc., Centerbrook, Conn.

Electronic Heating Generators

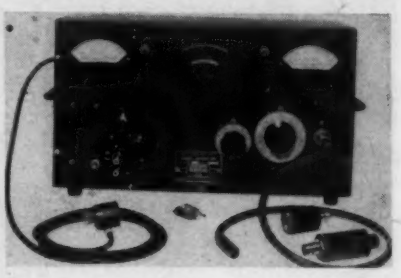
A COMPLETE LINE OF electronic heating generators with ratings of 1, 2, 5, 10 and 20 kw, in line with NEMA standards, are available for both induction and dielectric heating loads. These units are completely self-contained and have no external cooling or other auxiliary units. They operate on 60 cps lines. Units of 50 to 200 kw capacity can be supplied in addition to the standard 1 to 20 kw ratings. The primary voltage is 220 or 440, single phase for ratings of 5 kw or lower, and 3 phase for 10 kw and higher. The oscillator, power supply, blower, and other switchgear are housed in one unit. The high-frequency section is shielded to minimize the possibility of interference with nearby communications circuits. An automatic timing-control permits load cycle adjustment to a predetermined time, which can be automatically repeated. Terminals are provided for remote control. Air-cooled tubes are used in these generators.



Westinghouse Electric & Mfg Co., East Pittsburgh, Pa.

UHF Signal-Generators

THESE UHF SIGNAL generators (Type 804-CS1 and Type 804-CS2) are laboratory-type units which operate from 7.6 to 330 Mc and their frequency calibration is accurate to ±2 percent. Voltage output is controlled by an accurately calibrated attenuator network which allows control from 1 μv to 20,000 μv. The output of the instruments is arranged so that an internal source of modulation at a frequency of 1,000 cycles may be used, or, by use of an incorporated switching arrangement, external sources of modulation between 30 cycles and 20,000 cycles may be used, adjustable from zero to 60 percent, indicated by a direct-reading modulation meter.



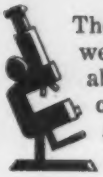
A special input circuit is used to pulse-modulate the generators from an external source, having very steep wave-fronts and extending in rapidity to pulses of approximately 20 microseconds. Shielding and r-f filters hold stray field leakage to a minimum. Frequency changes due to power-line fluctuations, are held to a minimum by the use of a stabilized power-supply, which is incorporated in the unit for operation on either 115 v or 230 v a.c., 40 to 60 cycles, single phase.

Each generator weighs less than 35 lb and comes supplied with a 3-ft coaxial output-cable of 75 ohms impedance, a fixed 10:1 attenuation reduction unit, a special terminal unit, an adapter plug, line cord, extra blank plug-in coil form, spare pilot lamps, fuses, and one set of 4 tubes.

Federal Mfg. & Engineering Corp., 211 Steuben St., Brooklyn 6, N. Y.

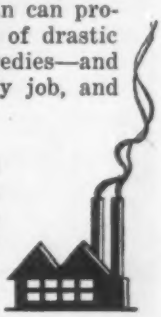
... as in the laboratory PLANNING IS FOREMOST IN THE NATION

America today is analogous to the laboratory where work is scientifically planned on foundations of the past, present, and future. The mistakes that the world made after 1918, the current conflict, and our hopes for the years ahead serve as the foundation components for a postwar program of peace and security and abundance. Like the laboratory technician, our country's thinkers should plan our participation on a scientific basis.



The objective of the nation is already established. You know that technical advancements, especially those in communications and transportation, have made isolationism and nationalism impossible. America, therefore, *must* participate in world affairs. Friendly relations in the international community mean not only an interchange of ideas, but an interchange of goods. Out of the former comes a better understanding of each nation's problems . . . out of the latter will come wider markets for our greatly expanded production. In gaining such markets, we can still maintain our industrial set-up as it stands today, yet avoid any of the ills that might arise from overproduction.

The effects of such a policy are closely allied to the welfare of the American people. An economy of abundance can be translated into an abundance of jobs . . . for present workers as well as men and women returning from the battlefields. Equally important, it gives our country the the opportunity to make even greater strides in securing the well-being of the individuals . . . be they capital or labor. Through such an economy of abundance, the businessman can protect his production peaks without fear of drastic reductions in sales, and resulting tragedies—and the worker can be assured of a steady job, and all that it implies.



We have the qualities for winning the war . . . that is certain. Whether or not we have the qualities for winning the peace remains to be determined. Should we recognize our nation as a huge laboratory, and ourselves as scientists, engineers and technicians working in the simplest, most direct method, we can achieve our goal of a just and lasting peace with opportunity and security for all.

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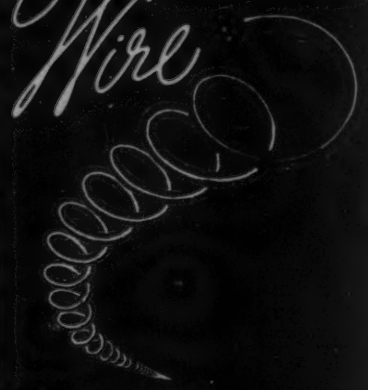

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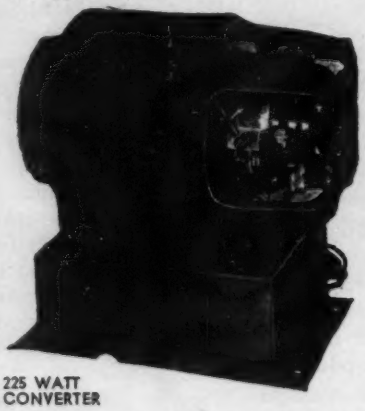

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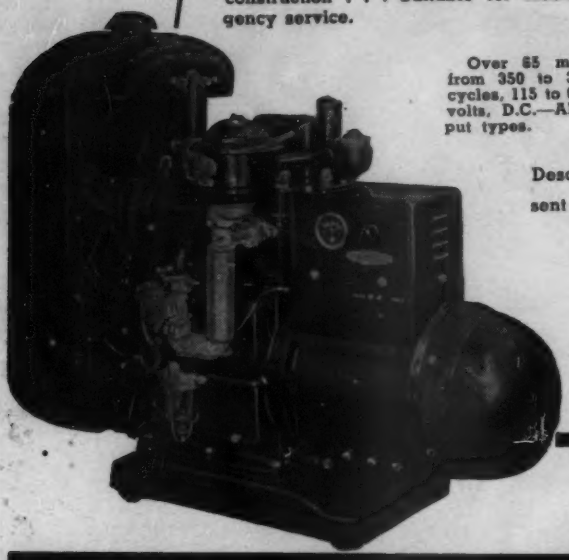

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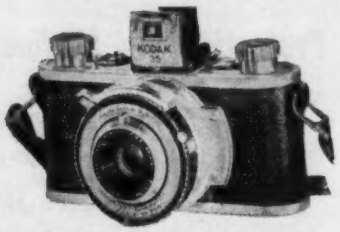

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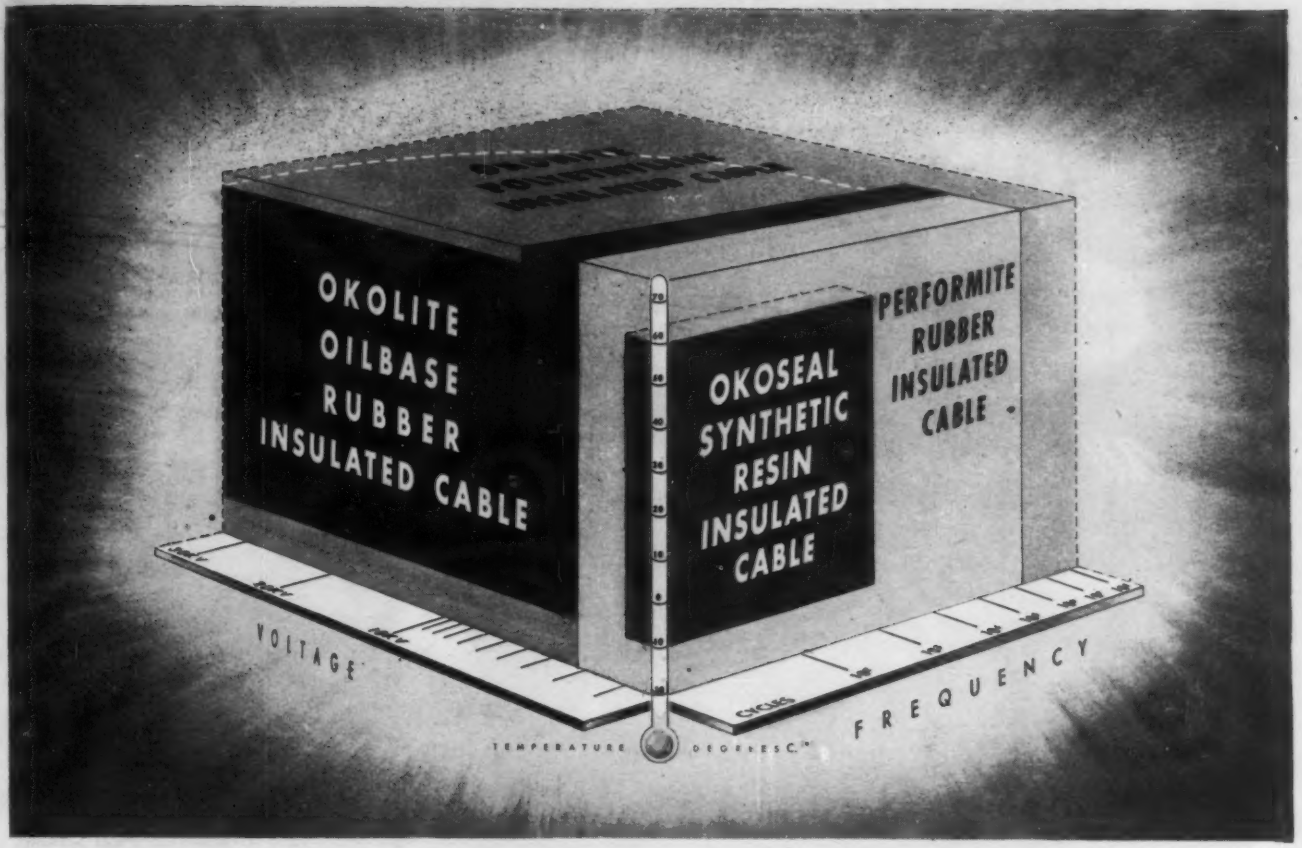

PERSPECTIVE: Selecting Insulated Cable Requires a Multi-Dimensional Approach

This 3-dimensional graph illustrates practical fields of usefulness of 4 widely-used types of cable insulation. Each type has particular characteristics that make it suitable for definite applications — but at the same time each possesses certain limitations.

The pictured values show the present maximum voltage, frequency and temperature limits for which these four insulations are commonly used. The insulations with the higher values can, in many cases, be used as alternatives for those having lower values.

Design engineers may find this rather unusual graph helpful in selecting a cable for some specific application. The problem, however, is not always as simple as indicated because it is often necessary to obtain cables having additional characteristics not covered by this graph — such as resistance to moisture, oil, chemicals, flame, etc.

Actually there are available many other insulations developed through Okonite Research — such as glass, paper, cambric, rubber and many synthetics — that cover the full range of electrical applications. Through intensive laboratory and long field experience, our engineers have acquired the over-all perspective that can help you select the *one* cable best suited for your purposes from *every* angle. Just outline your problem and let us make recommendations. The Okonite Company, Passaic, New Jersey.

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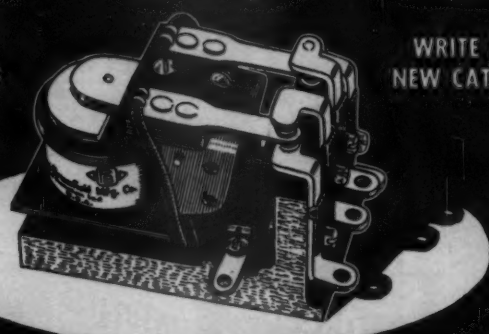
INSULATED WIRES AND CABLES

3760

COMPACT
SHOCKPROOF



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All Purpose **SP RELAY**

with Phenolic Base

Especially designed for communications equipment of all kinds, radio equipment, aircraft equipment and other applications. SP Relays are a general purpose relay with the ability to withstand shock and vibration. One-piece phenolic base and stationary contact support is resistant to the corrosive action of salt water and weathering. AC and DC types.

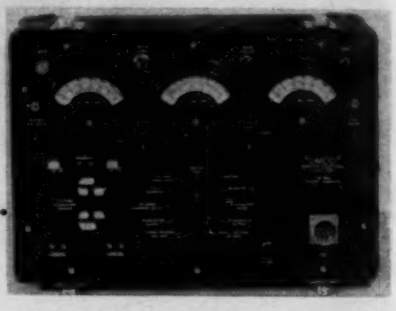
Potter & Brumfield
Princeton, Indiana
"THE POSITIVE ACTION RELAY"

have a linear rating of 3 w, V and W tapers are rated at 2; L, N. and U tapers, 1.5 w. Linear resistance values are from 1 to 75,000 ohms and tapered resistance values range from 10 to 50,000 ohms.

Clarostat Mfg. Co., Inc., 285 North 6th St., Brooklyn, N. Y.

Aircraft Electrical Analyzer

PRACTICALLY ALL wiring and electrical troubles of aircraft can be analyzed and located by a compact,



lightweight, portable testing unit which can be used for checking open circuits and shorts, for measuring resistances of any circuit element, and for testing and adjust-

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From many years experience in the production of ALNICO permanent magnets, The Arnold Engineering Company has prepared an authoritative, up-to-date manual of valuable information on the design, production and application of the modern permanent magnet.

Contents include such subjects as Magnet Materials, Resistance Comparisons, Physical and Magnetic Properties, Demagnetization and Energy Curves, Fabrication, Design and Testing. Charts and tables illustrate and explain various aspects of the discussion.

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Write *today* for your copy on your company letterhead.

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Specialists in the Manufacture of ALNICO PERMANENT MAGNETS

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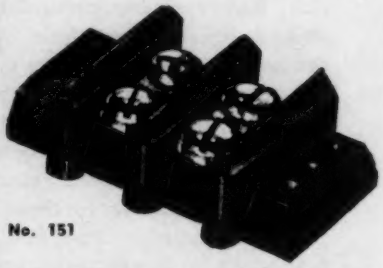
BARRIER STRIPS
SOLVE MOST TERMINAL PROBLEMS



No. 151

A compact, sturdy terminal strip with Bakelite Barriers that provide maximum metal to metal spacing and prevent direct shorts from frayed wires at terminals.

6 SIZES

cover every requirement. From ¾" wide and 13/32" high with 5-40 screws to 2½" wide and 1⅛" high with ¼"-28 screws.

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Many "missions" are aided to completion by technicians in the N-Y-T Sample Dept.

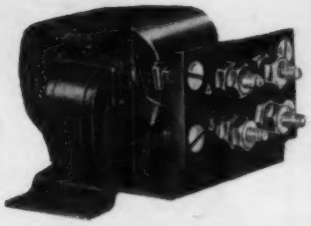
Whether the mission is accomplished by the Army, Navy or Air Forces—or is in itself a production job of Industry—the result attained, in all probability, had the backing of the N-Y-T Sample Department's engineering staff.

These electronic technicians are supplying a vital part of the custom-designed, specially-built transformers for leading suppliers of electrically controlled or operated apparatus and equipment. Applications covering communications, fire control, mechanisms, locating and directional devices, lighting systems, detecting, navigation, meterology, photo-electric units, and a host of other equally imperative phases of the war effort, are included in the Victory-function roster.

Missions will not terminate when hostilities cease. The myriad of peace-time problems will be unending . . . and will be accomplished by N-Y-T with the same zeal and thoroughness.

One of the many efficient power transformer designs that can be supplied in almost any voltage, frequency and power rating with mountings as required

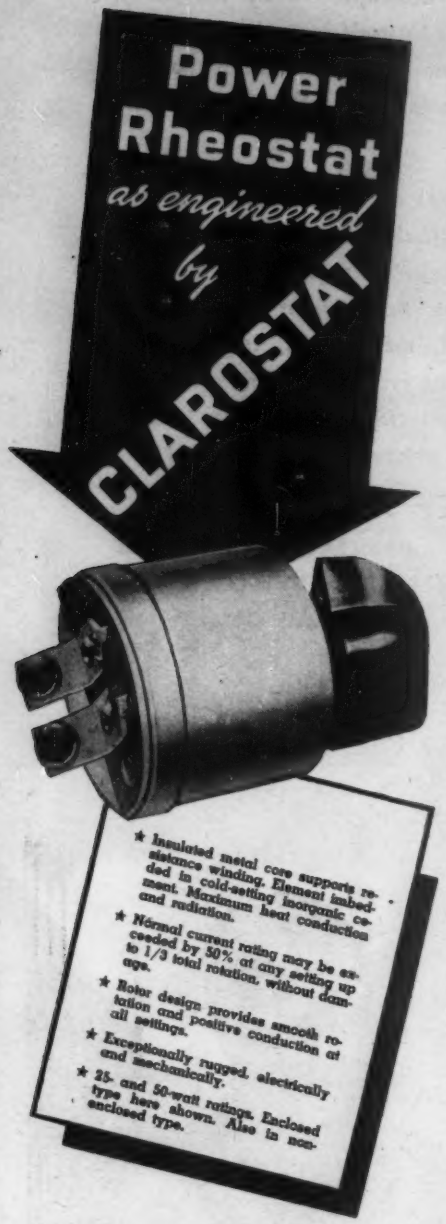
A diminutive audio component that incorporates unusual characteristics for such a compact unit. A typical example of N-Y-T resourcefulness.



This 30 V.A. power transformer features a 40% weight reduction over previous designs. Temp. rise 30° C. Ambient — 65° C to + 70° C. Weight 8 ounces!

NEW YORK TRANSFORMER COMPANY

26 WAVERLY PLACE, NEW YORK, N. Y.



★ Insulated metal core supports resistance winding. Element imbedded in cold-setting inorganic cement. Maximum heat conduction and radiation.

★ Normal current rating may be exceeded by 50% at any setting up to 1/3 total rotation, without damage.

★ Rotor design provides smooth rotation and positive conduction at all settings.

★ Exceptionally rugged, electrically and mechanically.

★ 25- and 50-watt ratings. Enclosed type here shown. Also in non-enclosed type.

★ Hundreds of thousands of these Clarostat power rheostats are now in daily use. They are standard equipment in planes, radio, electronic, and industrial equipment. They are proving that "they can take it"—and then some.

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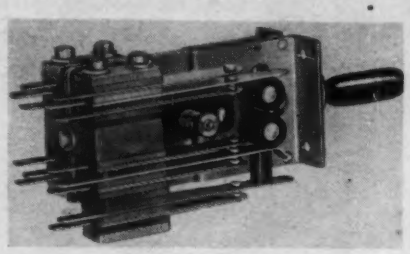
CLAROSTAT MFG. CO., Inc. · 285-7 N. 6th St., Brooklyn, N. Y.

ing voltage regulators and reverse-current relays. The unit, complete with all accessories weighs approximately 25 lb.

United Hydraulic Mfg. Co., Los Angeles, Cal.

Master-Cam Lever-Switch

A NEW MASTER-CAM lever-switch (Model MCL-CS) is designed for use in electronic and communications equipment, and wherever multiple circuits must be controlled. The switch is static-shielded and



non-corrosive. The positive positioning-cam has roller detents which eliminates friction and contact bounce. Coil springs are used on both sides of the cam, so that equalized pressure is assured regardless of the number or arrange-

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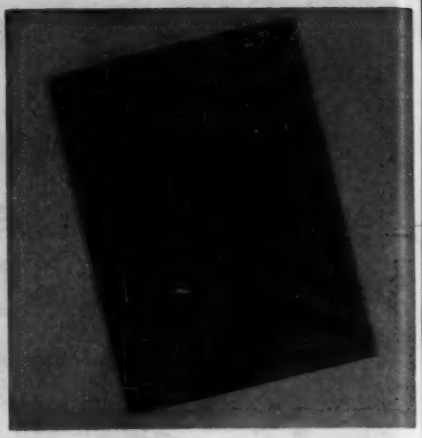
Applicants must comply with WMC regulations



A cut of JELLIFF .0008. ALLOY "C" WIRE was laid upon the above square . . . it is so fine, the camera almost missed it.

Below is a microphoto of the same wire, enlarged 420 diameters . . . a sturdy uniform wire.

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MANY years before "Electronics" blossomed as the wonder child of a post-war world, United Cinephone Corporation Engineers were putting Electronic devices to work for industry; devices which were practical, rugged, and down-to-earth.

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United Cinephone engineering and production facilities have proved valuable in many important industrial plants in connection with product control, automatic machine operation, operator safety and simplification of manufacturing methods. When our responsibilities as a Prime Contractor in the manufacture of military electronic equipment have been fulfilled, our facilities will again be at the disposal of industry.

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A typical military product of
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Just off the press—the new BAER descriptive bulletin! Contains factual, concise, vitally-pertinent data for the fibre-fabrication specifier or purchaser. What to use and what not to use for your particular application, from the standpoint of functional efficiency, service dependability and production economy.

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N. S. BAER COMPANY
CRAFTSMEN IN FIBRE FABRICATION
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ment of contact assemblies. All contacts can be removed from the frame by removing a single bolt. The control knob can be supplied with light or stiff action. Contact rating is 10 amps, 125 volts a.c., and 2 amps, 125 volts d.c.

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THIS MANUFACTURER has extended his line of mandrels so that approximately 750 different types are available for the forming of round, square, and rectangular paper tubes, used as coil bases. These mandrels are available for immediate use in many sizes, shapes and lengths, and any ID or OD, and handle kraft, fish paper, cellulose acetate, or combinations of these materials.

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TO AID RADIO manufacturers in obtaining accurate alignment of panel openings and contact points, minia-

This *New Jig Speeds* Your Radio Assembly

Send us your chassis or specifications for quotations. We are ready to meet your delivery schedules.

1) Can be loaded and unloaded in two seconds.

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A complete stock is ready for immediate shipment of quantities, ranging from 500 to 5,000 of each capacity in regular MICA CAPACITORS in 5%, 10% and 20% tolerance and silvered MICA CAPACITORS in 2%, 5% and 10% tolerances.

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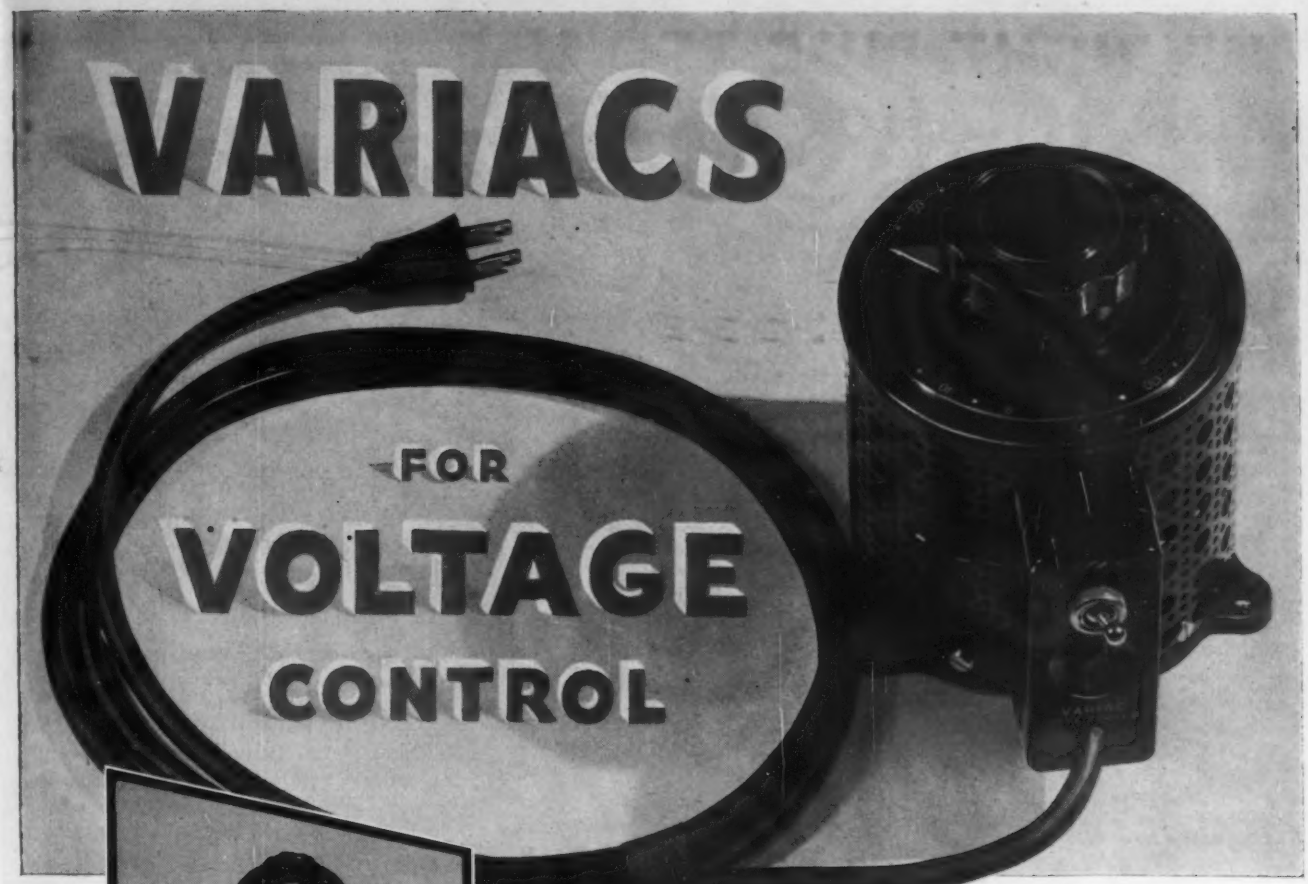
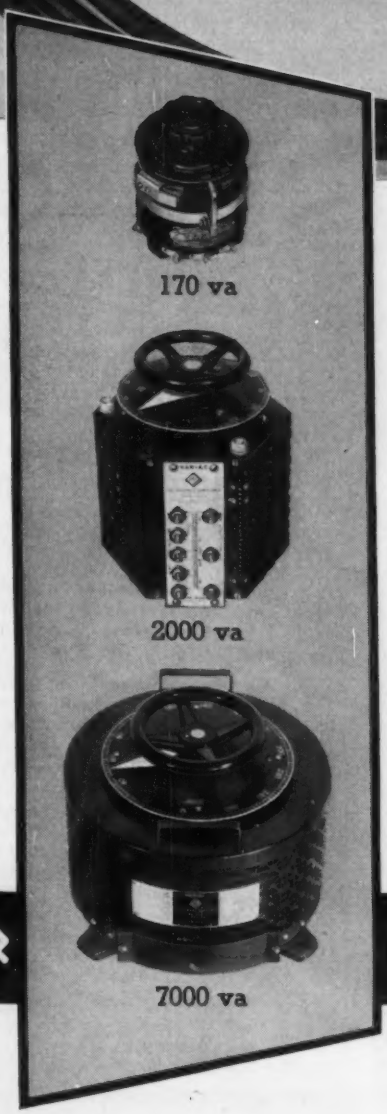
VARIACS

FOR VOLTAGE CONTROL





THE VARIAC . . . the *original* continuously adjustable, manually operated a-c voltage control . . . has these features:

- **SMOOTH CONTROL** — The VARIAC may be set to supply any predetermined output voltage with absolutely stepless variation.
- **HIGH EFFICIENCY** — Exceptionally low losses both at no load and at full load.
- **HIGH OUTPUT VOLTAGES** — VARIACS supply output voltages 17% higher than line voltage.
- **LINEAR OUTPUT VOLTAGE** — Output voltages are continuously adjustable from ZERO by means of a 320 degree rotation of the knob.
- **SMALL SIZE** — VARIACS are smaller than any other voltage control of equal power rating.
- **CALIBRATED DIALS** — VARIACS are supplied with reversible dials which read directly in output voltage both from zero to line voltage and from zero to 17% above line voltage.
- **ADVANCED MECHANICAL DESIGN** — Rugged construction; no delicate parts or wires; two or more units may be ganged on the same shaft for multi-phase operation.

VARIACS are stocked in nine models with power ratings from 170 va to 7000 va; prices range between $10.00 and $100.00.

Because all of our facilities are devoted to war projects, VARIACS are available at present only for War work; all orders must have a priority rating.

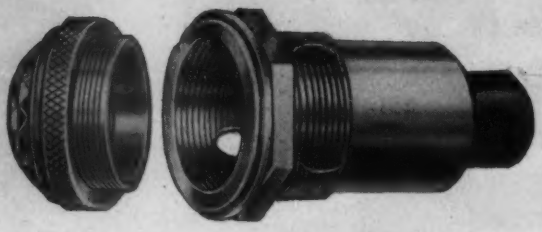
VARIACS are made *only* by General Radio

GR **GENERAL RADIO CO.** Cambridge 39, Mass.
NEW YORK CHICAGO LOS ANGELES

• WRITE FOR BULLETIN 883

THE RIGHT BULB TO USE NO LONGER A MYSTERY

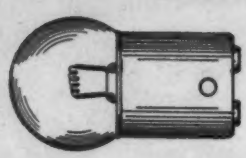
THE NEW GOTHARD CATALOG—is actually an Engineering Handbook that gives you this and complete engineering data on each of a wide range of models for varied applications. Here is an example of the information given:



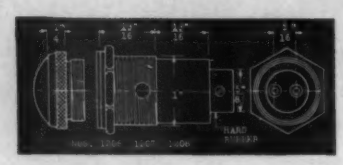
Mazda No. and Voltage of lamp received by each specific Pilot Light is given opposite each photograph.

Voltages:

Mazda No.	44	6- 8 Volt
Mazda No.	48	12-16 Volt
Mazda No.	72	18-24 Volt
Mazda No.	1252	24-28 Volt



Pilot Light Dimensions are presented in blue print diagram.



Specifications include essential data on panel thickness, mounting dimensions, metal substance, jewel colors, etc.

Request your copy immediately

Listings of
#1206 Faceted Jewel
#1207 Plain Jewel
#1208 Frosted Jewel, Colored Disc.

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MANUFACTURING COMPANY
1310 North Ninth Street, Springfield, Illinois

EXPORT DIVISION—25 Warren Street, New York 7, N. Y. *CABLES—Simontrice New York*

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With production redoubled, ICA is striding ahead of schedule—delivering Radio, Sound, and Electronic Products to the Armed Forces.

At the same time, we are planning ahead, and therefore suggest that you get the complete ICA picture now. Write for 48-page Catalogue and 8-page Brochure describing our products and manufacturing facilities.

Illustrated: ICA Antenna Installations are in wide use in the Armed Forces.

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ture dummy tubes and tube-pin straighteners are available.

Stainless steel pins are used in the dummy tubes, which are used to hold socket clips in correct alignment during wiring. The tube-pin straighteners are available with either hardened tool steel inserts (for factory use) or with stainless-steel inserts (where greater resistance to corrosion is desirable). Body and posts are plated with cadmium. Inserts are replaceable. Both the tubes and tube-pin straighteners meet requirements of the WPB Sub-Committee on miniature tube standards.

Robert L. Stedman Machine Works, Oyster Bay, Long Island, N. Y.

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QUICK ACCESS to contacts of small switches is facilitated by the use of solderless knife-disconnect terminals. Switches which have tabs extended from the contact, to which the external connections are soldered, may be converted readily to quick-disconnection switches without affecting the housing or any

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330 West 42nd St., New York 18, N. Y.

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***Units illustrated are designed for maximum intelligibility through high noise levels plus economy of installation. Recommended for areas where wide angle distribution of high frequencies are necessary. Complete technical bulletins describing the above upon request.**

Type 26-B is designed for voice reproduction when used by itself. Also an excellent high frequency component to a wide range system. Provides uniform distribution over horizontal angle of 120° and vertical of 40°. Handles power input of 40 watts when equipped with two Jensen U-20 drive units. 22" wide, 14½" deep, 20" high.

Type 24-A is primarily an outdoor speaker. At 50 watts input produces a sound level of + 94 db. (Zero reference level 10^{-16} watts per cm^2) at 100 ft. distance on the axis of horn. Two or four Jensen U-20 drive units allow a maximum of 50/100 watts input. 38" long, 26" wide, bell diameter 25".

Type L-360 is designed for 360° horizontal coverage and 40° vertical with uniform frequency and power distribution. Handles power input of 20 watts when equiped with a single Jensen U-20 drive unit. 23" in diameter overall; weight 25 lbs.

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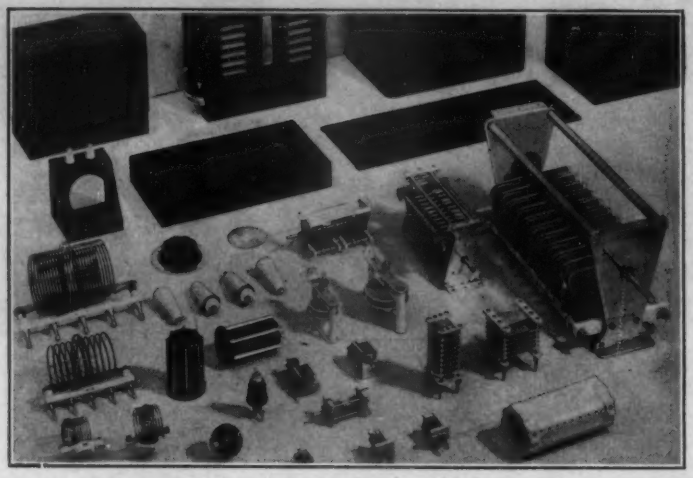
GIVE BUD YOUR SPECS



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BUD RADIO, INC.
CLEVELAND 4, OHIO

switch parts other than the contact members. Switches which have screws or binding posts for external connection may also be converted. These terminals may also be used as a soldering tab for emergency repair or replacement, where splicing terminals are not available on the external leads, or a solderless connection may be made, if desirable.

Aircraft-Marine Products, Inc., 1591-B North 4th St., Harrisburg, Pa.

Voltage Regulator

THIS A-C VOLTAGE regulator (Type TH Transtat) is a rotating transformer-type device. It is designed for use by manufacturers of small apparatus. Features include a brush arm which is an accurately-machined die-casting permitting good heat dissipation, and a simple means of changing brushes. It protects the commutator against short-circuiting contact with the brush holder. The shaft is independent of the brush-arm assembly and the unit can be quickly changed from panel mounting to table mounting, or ganged with other

Unusual Contact Designs
ARE NOT UNUSUAL TO GIBSON

2½ Times Actual Size

★ While war necessity does not permit release of information covering operational details we can present this illustration as an example of unusual design of electrical contacts being produced in our plant. It is a coin silver contact ring for use on an assembly of special ceramic parts and made expressly for Stupakoff Ceramic & Manufacturing Company, Latrobe, Penna. This contact is being manufactured in large quantities by punching, forming and butt-brazing, with tolerances held to ±.001" on I. D. and ±.002" on width.

★ Gibsiloy ELECTRICAL CONTACTS *Manufactured by* GIBSON ELECTRIC COMPANY 8361 Frankstown Ave. Pittsburgh 21, Pa. ★

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preferably a B. S. or B. A.
in ECONOMICS

Must have some background in market research and writing reports.

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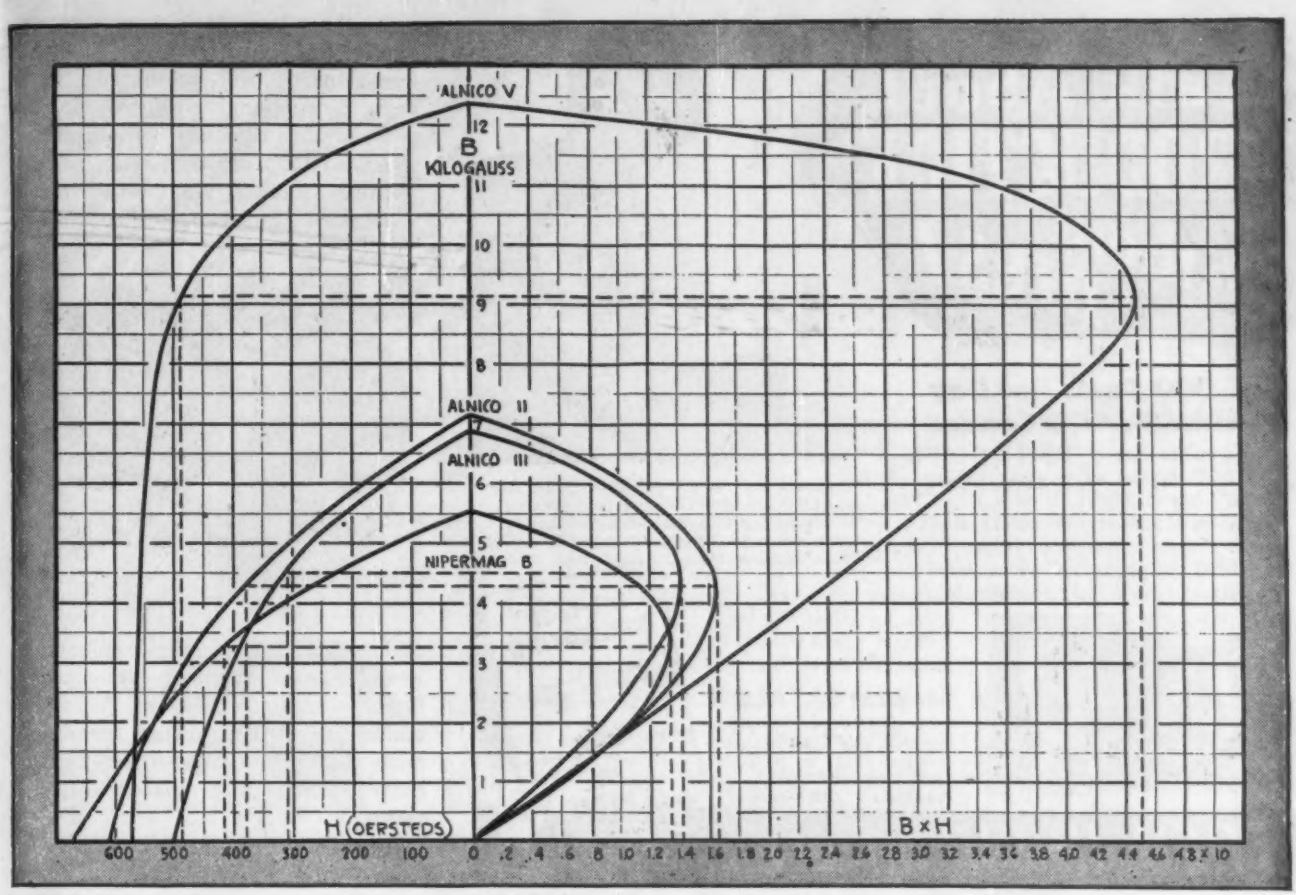


IMPORTANT CURVES

During our many years of service to industry in designing and manufacturing permanent magnets, we have conducted hundreds of tests. From the result of these tests we have been able to plot charts and nomographs for taking much of the guess out of magnet design.

The one shown above—"Typical Demagnetization and Energy Product Curves"—is used constantly by our own engineers in designing magnets from the various proved alloys. If you are designing your own magnets, these curves should be useful, particularly as they are accompanied by an instructive pamphlet—"Permanent Magnet Design".

Send for the chart and pamphlet. Try designing your magnets. We'll be glad to check your results.

CINAUDAGRAPH CORPORATION
2 Selleck St. Stamford, Conn.

Send for the chart shown above; also for a copy of "Permanent Magnet Design"

CINAUDAGRAPH CORPORATION

9-CC-2

Talk About PRODUCTION Without DIES!

"Enclosed pictures in our plant prove the DI-ACRO Bender will do a real production job. We are making 4,000 completed parts per day which is competitive to most Power Presses." (Name on request)

4,000 Parts Per Day with DI-ACRO Bender

Here is an example of "DIE-LESS DUPLICATING" typical of a great variety of formed parts readily made with DI-ACRO Precision Machines,—Benders, Brakes, Shears. Picture below shows an acute right angle bend and photograph above shows the finished part formed to die precision. Women operating DI-ACRO units maintain a high out-put on production work.

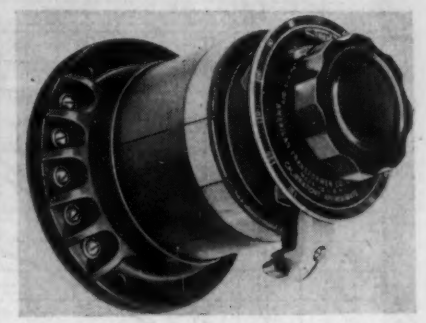
Send for CATALOG

showing DI-ACRO Precision Machines and many examples of parts made with "DIE-LESS DUPLICATING."
Pronounced "DIE-ACK-RO"

O'NEIL-IRWIN MFG. CO.

321 EIGHTH AVENUE SOUTH . MINNEAPOLIS 15, MINNESOTA

units for polyphase or simultaneous single-phase control. Accidental lead-shorting is prevented, and high dimensional conformance is assured by the use of phenolic thermosetting plastic parts. Other features include vinylacetal insulated-wire, impregnation of core



and coil with a synthetic-phenolic resin varnish of the polymerizing type, corrosion-resistant fittings, and a new dual mounting arrangement for open delta, three-phase control that reduces space requirements.

American Transformer Co., 178 Emmett St., Newark, N. J.

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SELF-LOCKING SET SCREWS Hold Against All Vibration

For assured dependability, use "UNBRAKO" Self-Locking, Hollow Set Screws with the KNURLED POINTS.

Past performances over long periods in a vast variety of applications have marked "UNBRAKO" Knurled Point Hollow Set Screws as uniquely SATISFACTORY, because they won't shake loose—come Hell and high water. They're strong and hard . . . their hex socket won't round . . . and they positively stay put.

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The "UNBRAKO" Hollow Set Screw With Knurled Cup Point. Pat'd. & Pats. Pend.

The Knurling of Socket Screws Originated With "UNBRAKO" Years Ago.

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Plug in for A.C. or 6-volt auto battery; no power pack necessary. Uses mike and built-in phono at same time. 78 RPM motor, 9-inch turntable, crystal pick-up, separate on-off switch. Long-playing needle included. Continuously variable tone control on inclined eye-level control panel. Use one or two 8-ohm speakers without need of extra transformer. Has one 6SJ7GT, one 6SC7, two 6L6Gs in push-pull, two 6X5GTs.

Model 6720, with tubes, F.O.B. New York **$56.28**

Model 6721, same as 6720, less phono player **$42.87**

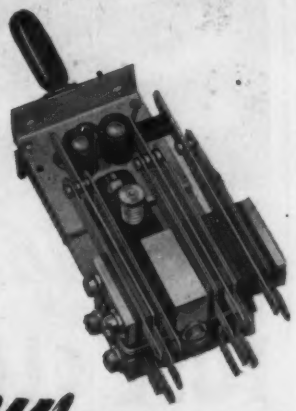
TERMINAL RADIO CORP.

85 CORTLANDT ST. NEW YORK 7, N.Y.

PHONE WOrth 2-4415

two new Master CAM LEVER SWITCHES

GENERAL CONTROL COMPANY



New MODEL MCL-CS

General Control Company, the original cam lever switch specialists, are pleased to announce two new cam lever switches. The new Model MCL-CS is similar in design to the well-known Model MCL-FS, except that coil springs are used instead of flat springs to assure longer life and equalized pressure on both sides of the cam, regardless of the number or arrangement of contacts on each side of the switch. Also it can be supplied with either light or stiff action on the control knob to suit your requirements. This model is rated at 10 amperes, 125 volts A.C. and is outstanding for long life and dependability.

New MODEL MR ROTARY

The new Model MR Rotary Cam Lever Switch is designed for one to six index positions. It fills a definite gap, and a definite need, in the multiple contact switch field. With the new Rotary, any combination of contact arrangements can be used in each of the six positions. It is adaptable to actuate practically any number of circuits in sequence (or repeat) with the convenience of a single control knob. Its unique construction provides such features as circular cams for locating from one to five low-friction, roller spring actuators on each cam. A single hole only is required for mounting, and contacts in any section can be removed from frame by removing a single bolt. This switch can be easily rearranged. The Rotary is rated at 10 amperes, 125 volts A.C.

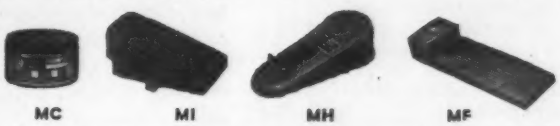
OTHER GENERAL CONTROL COMPANY PRODUCTS

MODEL MCL-FS

Same construction as MCL-CS except with flat springs for pressure on cams. Contact possibilities are unlimited.

MODEL MCL-MT

Now under development for aircraft and other light duty applications. The lightest switch of its type in the field.



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These switches relieve the machine operator, prevent fatigue, increase production and safety. The 35 types cover every application. Send for catalog No. 441.

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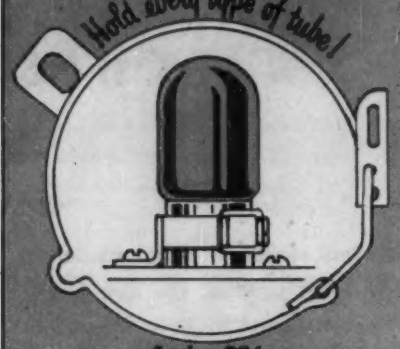
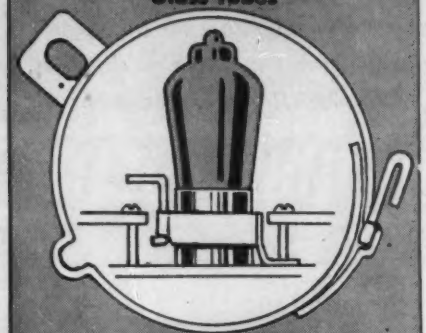
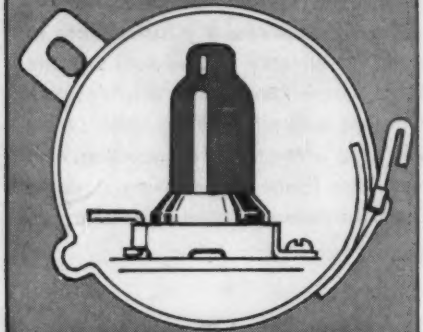
LOCKING TYPE
TUBE
CLAMPS



Series 926
for Chassis Mounted
Glass Tubes



Series 930
for Sub-Chassis Mounted
Glass Tubes



Series 929 For Metal Tubes

Birtcher Clamps are suitable in all applications requiring a sturdy, positive-action device for securely holding tubes and similar plug-in components in their sockets under extreme vibration stresses.

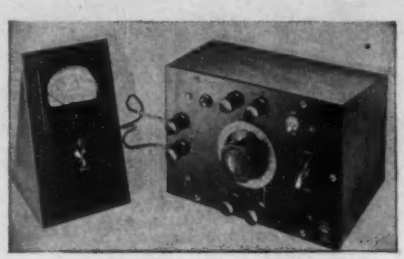
PROMPT DELIVERY

Samples and Prices Upon Request

THE BIRTCHER CORPORATION
Manufacturers of AIRCRAFT and RADIO PARTS
5087 HUNTINGTON DR. LOS ANGELES 32

Comparison Bridge

FOR SPEEDY TESTING of resistors, capacitors or inductors in terms of ohms, microfarads or henries, respectively, the Type LB direct-indicating comparison bridge may be used. Components under test are connected one by one to terminals and are then rejected or passed. Components outside the limits set up (limits may be set with any combination of high or low value,



such as −6, +14 percent) will result in a meter deflection.

This production-test instrument is an a-c slidewire bridge with a vacuum tube null-indicator arranged so that resistors, capacitors or inductors can be compared with a similar standard. Ranges are:

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We are fully licensed to manufacture the complete BIRTCHER line of locking type, stainless steel tube clamps. Orders placed with us for prompt delivery using BIRTCHER part and identification numbers will be filled at prices as favorable as those to which you are accustomed. All clamps will be identical with those manufactured by the Birtcher Corporation.

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THE GEORGE S. THOMPSON CORPORATION
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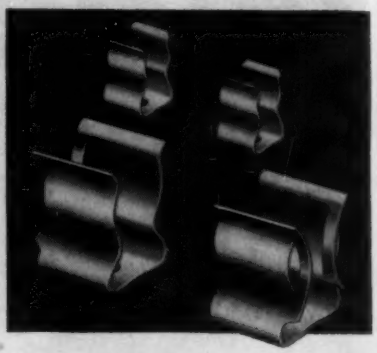
LOS ANGELES 32, CALIF.

COMPLETE CIRCUIT PROTECTION

requires Fuse Clips especially engineered to the multitude of today's services.



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FUSE CLIPS

PHOSPHOR BRONZE • BERYLLIUM COPPER, SILVER PLATED

In aircraft, communications, industry, electronics, electrical products—from most delicate meters to high voltage services, Littelfuse solves the problem with new *improvements.*

Exclusive Littelfuse design and forming effect *contact over largest possible area.* Results: Extra tight grip—maximum electrical conduction—less heat produced—panel board and switch temperatures reduced—loss of clip-temper prevented—spring qualities retained much longer.

Whatever your fuse clip requirements, Littelfuse will be glad to counsel with you.

Littelfuse equipment on Pan American Clipper. Courtesy of Pan American Airways System.

LITTELFUSE INC.
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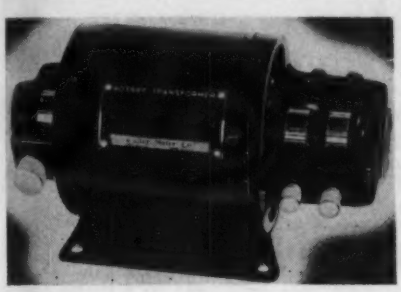
capacitance, between 0.0001 to 1.0 mfd; resistance, between 2000 ohms and 20 megohms; inductance, between 5 and 50,000 henries. The slidewire is uncalibrated. External standards are used. The instrument comprises a main unit which measures 7 x 8 x 5½ in., and a separate meter.

Industrial Instrument, Inc., 17 Pollock Ave., Jersey City, N. J.

Multi-Output Dynamotor

THIS PIECE OF equipment is designed to save space and battery current in mobile applications, particularly where a transmitter and a receiver are used. The dynamotor is capable of delivering simultan-



eously as many as three separate outputs. For instance, it is possible to obtain 6.3 volts a.c., "B" power for the receiver, and also high voltage for the transmitter.

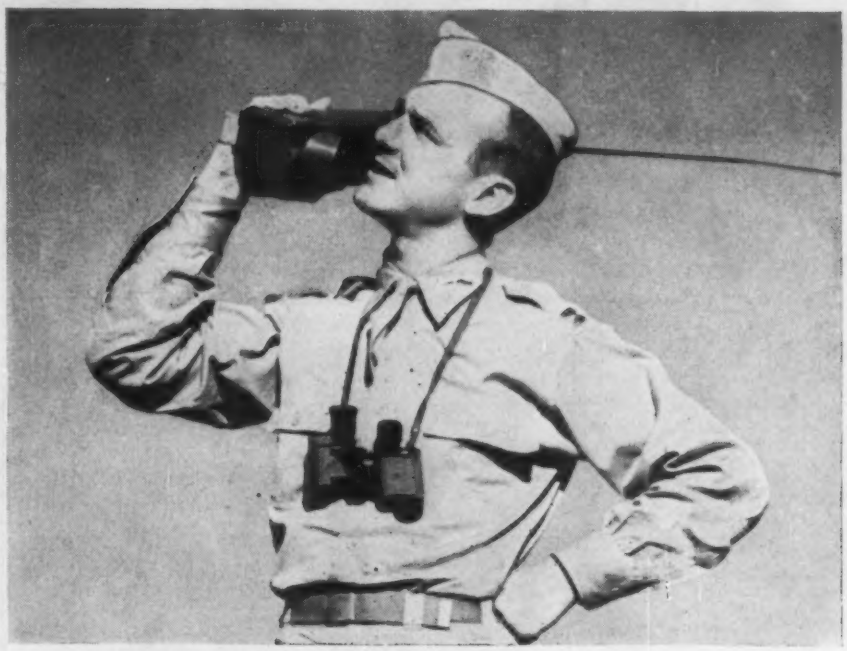
Carter Motor Co., 1608 Milwaukee Ave., Chicago, Ill.

Constant-Voltage Transformer

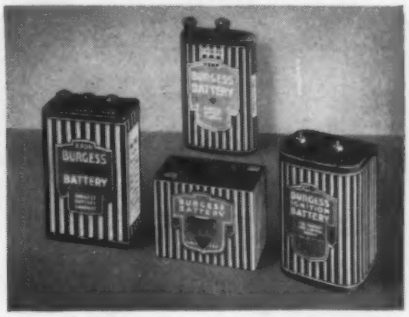
ILLUSTRATED BELOW is a small, compact unit in a hermetically sealed case, designed for chassis mounting. Rated at 6.3 v, 17 va output, this constant-voltage transformer will maintain that value within ± 1 percent regardless of line-voltage variations as great as ± 12 to 15 percent. This unit is especially

PORTABLE POWER PROBLEMS

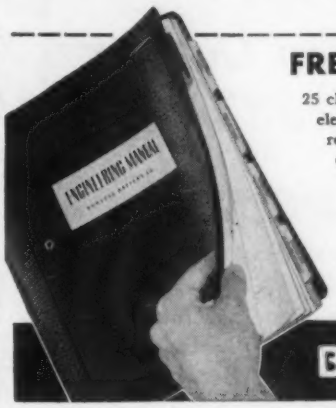
THIS MONTH—SIGNAL CORPS' "HANDIE-TALKIE"



A POWERFUL HANDFUL, capable of calling tanks and planes for support or attack, the "Handie-Talkie" is the electronic answer to modern warfare's demand for a light, compact communication unit. Lightweight Burgess Batteries give the "Handie-Talkie" necessary energy to operate under all conditions and in any climate.



SPECIAL-PURPOSE BATTERIES. The battery needed to operate the "Handie-Talkie" was developed by Burgess engineering research to give dependable service wherever the Army goes. Burgess engineers are constantly creating new special-purpose batteries, and new uses for standard batteries. Let them solve *your* portable power problems. Write about your specific needs, or *send coupon below for free Engineering Manual.*



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25 charts and 36 data tables on characteristics of dry batteries for electronic applications. Also 31 descriptive pages. Tabbed for ready reference. Write Dept. 9 for *free* copy. *Burgess Battery Company, Freeport, Illinois.*

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MANUFACTURING COMPANY
INCORPORATED
Forestville, Connecticut

suitable for use in stabilizing electron-coupled oscillator circuits. Electronic equipment in which this transformer is included does not require filament voltmeters or manual filament-voltage controls.

Bulletin DCV-102 describes this and other new designs of transformers available from the manufacturer, Sola Electric Co., 2525 Clybourn Ave., Chicago 14, Ill.

Impluse-Initiated Timer

TYPE PSEH-1 TIMERS can be supplied for a-c operation on 110 or 220 v, 60 cycles or 25 cycles; or for d-c operation at any specified voltage from 6 to 120 v. Typical units measure 3½ x 3⅝ x 3¾ in. Contact operation occurs at the end of a delay interval after power has been applied, or after receipt of a momentary impulse from a pushbutton, limit switch, or other source. The adjustable timing range is 20-to-1, and the mechanism is immediately recycling. A built-in DP, DT auxiliary relay provides a variety of circuit arrangements common to, or isolated from, the control circuit.

Struthers-Dunn, Inc., 1321 Arch St., Philadelphia 7, Pa.

Pivot Type Ball-Bearings

PIVOT TYPE BALL-BEARINGS are available in sizes ranging from 2 to 10 mm O.D. They are made of beryllium, stainless or chrome steel. Each bearing is equipped with four balls of the same material as the cup, and fitted with a retaining cup.

Miniature Precision Bearings, Keene, N. H.

Triple-Action Locknuts and Fasteners

THE MAIN FEATURE claimed for Type 6NAC Palnut locknuts and fasteners is a triple locking action. The sides have been extended and the ends of the petals are turned in, leaving a hole in the top slightly smaller in diameter than the outside diameter of the bolt. When the bolt extends through the top, it forces the top open so that a strong spring pressure is exerted on the bolt, resulting in a triple grip. Because this spring tension is constant and will hold the nuts in any desired position on the bolt regardless of vibration, this type of nut may be used as an adjustment nut

HERMETICALLY SEALED
Sensitive RELAYS

TO WITHSTAND
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The 4R and 5R Relays may now be obtained hermetically sealed. Truly proof against fungus, humidity and other tropical hazards — capable of withstanding ambient temperatures from −50° to +90° centigrade.

Exposed insulation is glass. The assembly is permanently sealed with solder. Plug-in mounting or lugs for permanent or semi-permanent installation. Tie-down lugs for either type if desired.

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For Stationary Operation.
Type 4 requires 6 to 12 mw
—is very fast operating
Type 5 requires 0.5 mw
—is slower than type 4

For Aircraft Applications, etc.
Type 4 requires 30 to 50 mw
Type 5 requires about 5 mw
—is most stable as to adjustment.
—withstands severe shock (500 g's) without damage.

Send for complete information, stating your problem.

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NEW ADDRESS 62 CEYLON STREET
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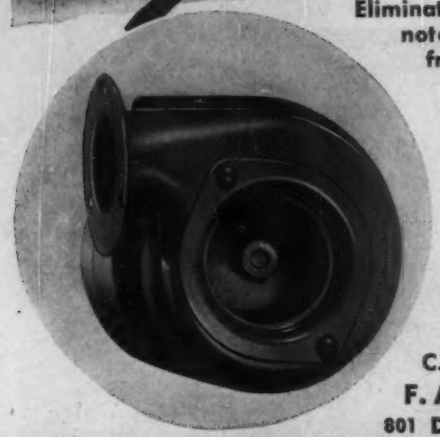
PEAK EFFICIENCY.... LONGER LIFE for Electronic Equipment



Eliminate set generated heat and you get not only *peak efficiency* but *longer life* too from all components parts in electronic equipment. Pilot Blowers are proving this for leading manufacturers in this field. Easy-to-install—compact—quiet running—economical... these are the features which make Pilot Blowers ideal for the important job of air circulation and ventilation in Radio equipment. Available in standard models to move from 15 to 110 C.F.M. Write for Bulletin 507 today!

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PERMEABILITY	HIGH	
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Type 6NAO nuts may also be used, because of their light weight, on bolts holding together parts made of glass, plastic and other such materials, where a resilient fastening is required that can be tightened without danger of fracturing relatively brittle materials. Another feature of these Palnuts is that they are all-metal and will therefore withstand high temperatures.

The Palnut Co., 77 Cordier St., Irvington, N. J.

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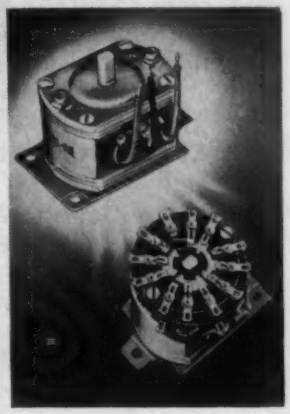
RO-TROL is a new type of relay which operates on a rotating balance principle. It is designed especially for applications involving severe vibration, temperature and humidity specifications. The basic unit is a compact driving-mechanism providing up to 30 deg of clockwise or counter clockwise rotation. When used to operate switch



wafers, the basic unit makes a relay providing a great variety of contact arrangements adaptable for spaced wafer switches, or switches in separate compartments. Where switch wafers are not used, a special self-contained coil break-switch is provided. The unit measures 2½ x 1½ x ¾ in.

Price Brothers Company, Frederick, Md.

Coaxial Plugs and Jacks

TO MAKE SOLDERING of coaxial plugs and jacks an easy and out-in-the-open job, these plugs and jacks are built with sliding sections so that they can be quickly disassembled. The conductors to be soldered are

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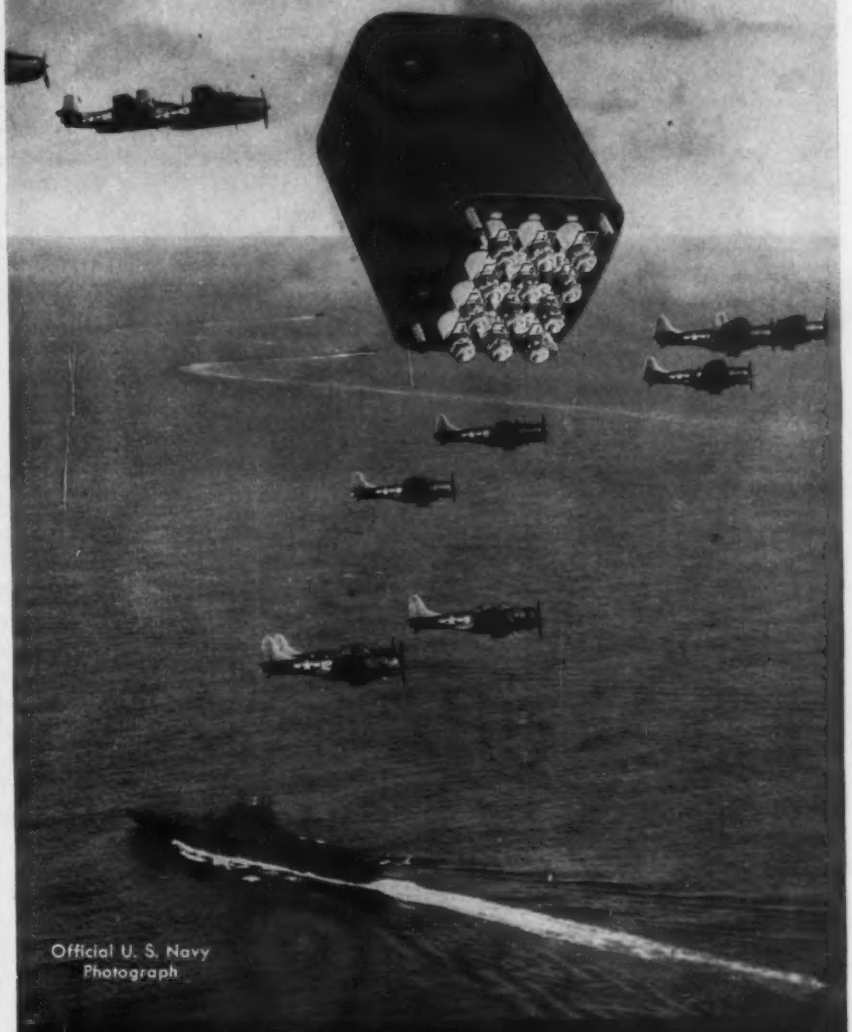
Chicago Transformer designs and manufactures transformers that more than meet the rigid standards set for equipment of this type.



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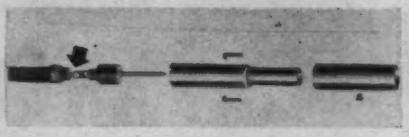

easily exposed by removing one screw and sliding the sections apart with the fingers. It is not necessary to solder through a window. These plugs and jacks are machined from bar brass and have positive connection between outer conductor and inner conductor. The inner-conductor contacts are silver plated for maximum conductivity. Mycalex is used as insulation.

Andrew Co., 363 East 75th St., Chicago 19, Ill.

Fungus-Proof Resistors and Switches

FIXED WIRE-WOUND resistors (Akra-Ohm), and switches which have been treated with anti-fungus materials and which meet Signal Corps Specification No. 71-2202A are available without any manufacturing delay occasioned by this special treatment.

Shallcross Mfg. Co., Collingdale, Pa.

Aircraft Push-Pull Circuit Breaker

KLIXON D-6751 designates a new aircraft circuit-breaker which makes use of a push-pull feature to permit the opening of the circuit breaker manually. Thus maintenance and repairs to a circuit can be accomplished without de-energizing the entire power system. A deliberate pull is required, and the off position is retained safely against accidental tripping when operating adjacent switches. The push-pull button travels outwardly approximately ¼ in. upon tripping and ex-

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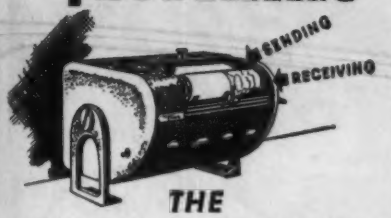

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"INSTANT COURIER"

(Transmits pictured messages by radio or wire)

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Immediate Delivery!

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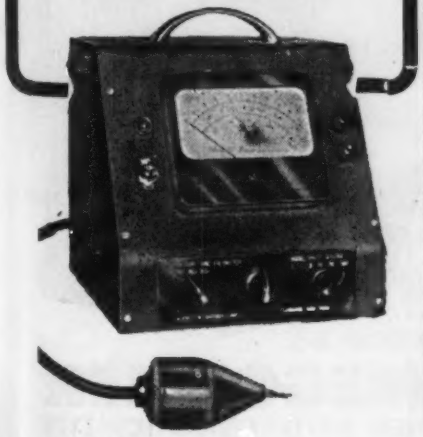
VOLTMETERS



- High input impedance for both AC and DC measurements.
- Convenient, low capacity "Probe," especially adapted to high frequency radio use—100 megacycles and over.
- Self-regulating operation from power line; no batteries.
- Multiple voltage ranges—accurate and stable.

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- Will not turn.
- More readily applied than a clinch nut.
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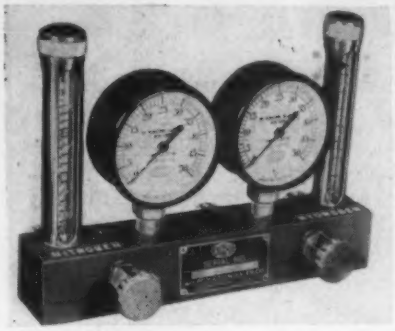

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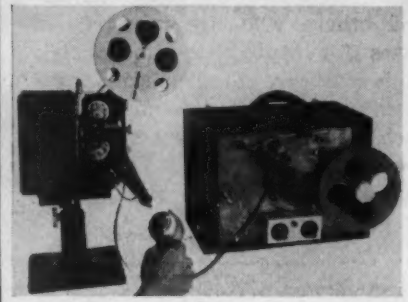
FILMGRAPH IS a new device for permanently recording and reproducing sound on film instantaneously and without processing. The instrument consists of an electromagnetic dual-purpose head (recording and playback), sapphire stylus, motor, and necessary controls and connections. It is available in a cabinet complete with an amplifier, speaker and microphone, (weight is 16 lb), or without these



accessories. Recordings can be made on Filmgraph M-5 special film, on which a number of sound tracks (up to 40) may be recorded, or a recording may be made directly on 16 mm film. Recordings cannot be made directly on 8 mm film because the speed of 8-mm projectors is too slow for good results on this recorder. Where it is desirable to use 8-mm film, it is necessary to use Filmgraph M-5 film as an auxiliary.

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TWO TYPES OF welding controls are available. The first of these is Model 40, which is a general-purpose control for seam, spot, or pulsation-welding machines. It is designed for the control of welders

KIRKLAND Pioneer
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D/E DOME TYPE LENS-CAP with HEAVILY WALLED, DEEPLY CUPPED GLASS LENS. SO OUTSTANDING THAT A COMPLETE LINE OF PILOT-LIGHTS HAS BEEN EQUIPPED WITH IT.

For Use With the Most Readily Obtainable Lamp Bulbs

Type No. 590 D/E Unit for use with the S6 candelabra screw base lamp on voltages up to 120 volts.

The No. 590 D/E Unit, List Price, (less lamp) $1.25.

Specifications: Mounting hole, 7/8" diameter; overall depth behind the front of the panel 2"; length of threaded area 1 1/16". Underwriters' Approved.

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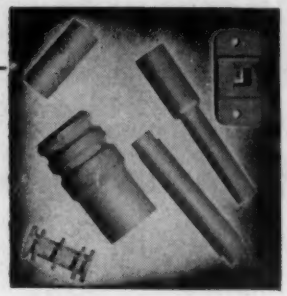
Lavite **STEATITE CERAMIC**



CHARACTERISTICS

Specific gravity of only 2.5 to 2.6 cent. Per cent power factor. Water absorption S. 1.5-0.001 per S. 1.5 to 60 cycles was only 0.0165. Dielectric constant at 60 cycles was 5.9-1000 KC 5.4.

Makers of electrical and radio apparatus destined for war service are finding in LAVITE the precise qualities called for in their specifications . . . high compressive and dielectric strength, low moisture absorption and resistance to rot fumes, acids, and high heat. The exceedingly low loss-factor of LAVITE plus its excellent workability makes it ideal for all high frequency applications.

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where more than one kind of operation is to be controlled by a single general-purpose control, and particularly where more than one type of operation is to be performed interchangeably on the same machine.

Model 41 is specifically designed for production seam-welding control. Heat and cool times repeat automatically for continuous seam-welding until interrupted by the operator. This unit is simple to adjust and is easy to maintain.

Bulletin No. WT-40-41 illustrates and describes these units in greater detail. It is available from the manufacturer, Weltronic Co., 19500 W. Eight Mile Road, Detroit 19, Mich.

Literature

Television Pamphlets. Two companies have issued brochures on television:

The first of these is entitled "Television" and the purpose of this 24-page book is to tell the advances of television; its progress and promise. A map is included which tends to show how east and west may be linked in a television network. Department of Information, Radio Corporation of America, 30 Rockefeller Plaza, New York, N. Y.

The second booklet is entitled "The Story of Electronic Television" and it attempts to tell the layman in simple language, and with illustrations, how television is accomplished. Two pages in the back of this 28-page book are devoted to television equipment available from the manufacturer, Farnsworth Television & Radio Corp., Fort Wayne 1, Ind.

Transformer Buletin. A complete range of transformers for small and large electric power requirements are illustrated and described in a bulletin entitled "Standard Transformers For Every Need" available from Standard Transformer Co., Warren, Ohio.

High Frequency Electrical Insulation. The manufacture, surface treatment and precision grinding of ceramics is discussed, and a

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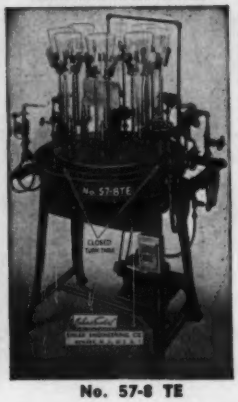

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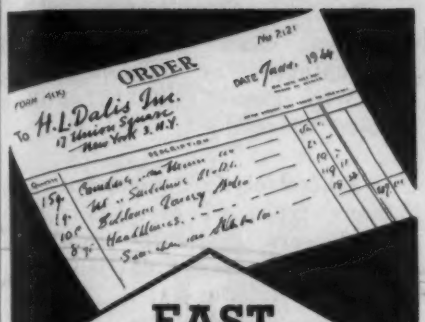

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table of mechanical and electrical properties is included in Bulletin No. 143. The bulletin also describes and illustrates insulators made of this ceramic material (which is designated A1SiMac No. A196). American Lava Corp., Chattanooga, Tenn.

Thermoswitches. The purpose of this catalog is to introduce the complete line of standard temperature and pressure control apparatus made by this manufacturer. It contains 44-pages of descriptive material, including installation drawings and photographs, plus a brief history of the company. Fenwal Inc., 200 Pleasant St., Ashland, Mass.

Flexible Shaft Machines. Catalog No. 130 illustrates and describes machines for light production work and for maintenance needs on small irregularly-shaped parts which cannot be handled by conventional machine set-ups. Available accessories are also described. Foredom Electric Co., 27 Park Place, New York 7, N. Y.

D-C Motor Control. "Electronic Control of D-C Motors" is a reprint, with changes, of a series of articles on this subject by E. E. Moyer, which appeared in 1943 **Electronics.** This reprint is designated as Filing No. 8930 and the articles in it are "Outline of General Principles", "Reference Voltage and Speed - Control Methods", Extending Speed Range by Electronic Means of Field Weakening", "Starting, Stabilizing, and Reversing", and "Regeneration by Inverter Action, and Stopping." Electronics Section, Industrial Control Engineering Div., General Electric Co., Schenectady, N. Y.

Springs. Catalog No. 44, entitled "Springs for All Purposes", contains a spring design chart. When he dimensions, load and travel distance is known, this chart may be used to find the number of coils and the proper wire size which one should use. Round or square wire 0.006 to 0.375 in. diameter, and strips of 0.003 to 0.187 in. thickness, and of any desired material are available. Types of springs illustrated in the catalog include compression, extension,

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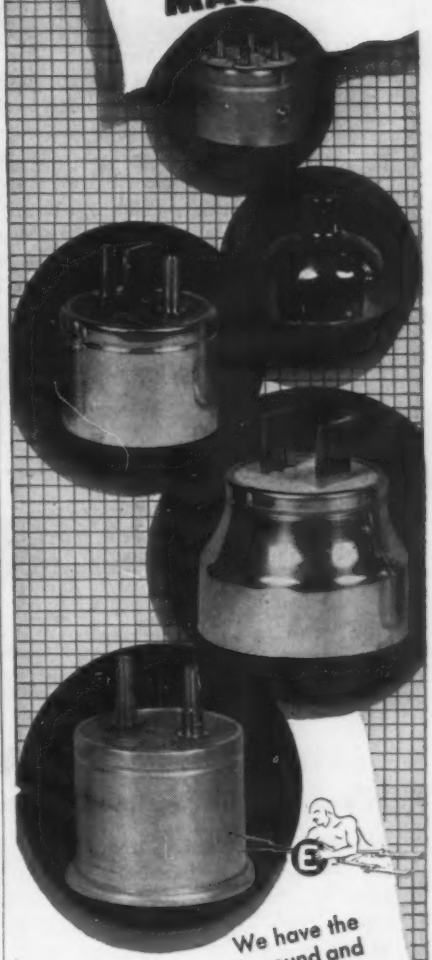

We have the engineering background and modern production facilities for the precision manufacture of Electronic Tube Bases, Caps, Tungsten Leads and Glass Working Lathes up to 6" for transmitting tubes. Consult our Engineering Department on your "special design" problems.

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BRANDING on PLASTICS!

WE SHOW YOU HOW
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However, wartime demands for this service in some ordnance plants, have required the application on their own premises. So, Rogan engineers have arranged a method whereby anyone can do his own branding on plastics right in his own plant. Rogan will engineer each job completely and build all the necessary tools. Will provide clear, simple instructions that will permit anyone to do the job expertly. All you need do is to send us blue prints and other specific data, and we'll give you a quick cost and time estimate.

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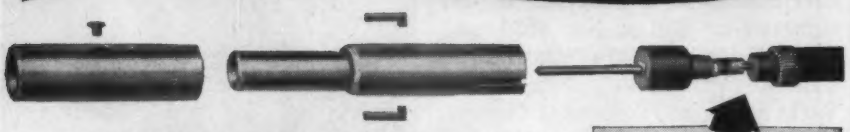
ANDREW COAXIAL PLUGS AND JACKS



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ANDREW coaxial plugs and jacks are used as connectors for flexible coaxial lines, and fit many of the standard Army and Navy approved cables. They are especially useful where a simple panel mounting plug-in type of connector is required.

Machined from brass bar stock, these sturdy plugs and jacks provide a positive connection between the outer conductors and between the inner conductors. Inner conductor contacts are silver plated to obtain maximum conductivity. Insulation is the best grade of Mycalex. Patch cords are made of low-loss flexible coaxial lines of 72 ohms surge impedance. Patch panels consist of 24 jacks mounted on a 19" relay rack panel.

ONLY ANDREW offers this easy accessibility for soldering.

You don't have to solder through a window to install an ANDREW plug or jack. Just remove one screw, slide the sections apart with your fingers and solder. This is a new improvement invented and used exclusively by ANDREW.

WRITE FOR BULLETIN NO. 31

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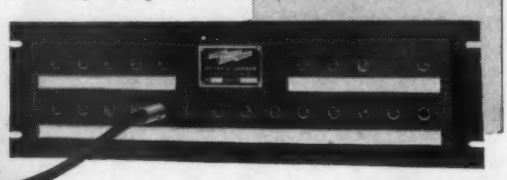

Illustration shows panel with patch cord in place.

torsion, clock type, slips and stampings. The Reliable Spring & Wire Forms Co., 3167 Fulton Road, Cleveland 9, Ohio.

Dry Electrolytic Condensers. The many types of dry electrolytic condensers available from this manfacturer are described in Catalog No. 10 which also contains application notes, characteristic charts and size factor tables. Sprague Electric Co. (formerly Sprague Specialties Co.), North Adams, Mass.

Handy Folder. A handy folder, Form C-112-5-4-44, labeled "Federal Telephone and Radio Equipment" is available. It contains literature put out by this manufacturer on Intelin coaxial u-h-f cables; booklet No. C-101-3-2-4 which describes type No. FTR-3 transmitter; booklet No. C-103-3-3-44 on type FTR-5 transmitter. Both of these transmitters are multi-unit types. Also included in the folder are two pieces of literature describing the Megatherm electronic heating unit. One booklet is devoted to the plastics industry, while the other booklet describes sterilization of packaged foods. Federal Telephone & Radio Corp., Newark, N. J.

Questions and Answers on RCA. This 48-page catalog entitled "RCA, What It Is, What It Does—Questions and Answers" is exactly what the title implies. The catalog is carefully indexed according to subject matter. Subjects include research and engineering, pioneering, broadcasting, television, manufacturing, communications, marine radio and technical training. Radio Corp. of America, 30 Rockefeller Plaza, New York 20, N. Y.

Smoke and Combustion Control. Indicators, controllers and recorders for smoke and combustion controls are illustrated and described in an 8-page folder form (Bulletin No. 431). Ess Instrument Co., Fort Lee, N. J.

Resistors. A new 28-page catalog (No. 10E) includes specifications and engineering data on the complete line of Koolohm wire-wound resistors. Resistor Div., Sprague Electric Co., North Adams, Mass.

SURCO-AMERICAN PLASTIC TUBING

Temperature extremes from 295°F. to minus 80°F. are just one sample of the varied conditions which "Surco-American" flexible plastic tubing is able to meet. Over twenty-six different formulations provide positive and tested qualities such as ageless durability, non-inflammability, tremendous flexibility, and proof against moisture, all kinds of weather, dilute acids, oils and most solvents.

Dielectic strength averages 1500 volts per mil. thickness. "Surco-American" is available in any color and in continuous lengths with inside diameters from .005" to 2". Exclusive packaging methods maintain this tubing in its original round form.

Flexible plastic insulated wire is another "Surco-American" pre-tested product—available in all lengths and colors and in wire sizes #12 to #48 A.W.C., solid or stranded, shielded, tinned or silver plated copper wire and cable.

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Special tubing, tape and wire, extended and molded plastic parts made to specifications.

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PROVIDES electronically regulated power supply for general laboratory and production testing. Especially useful to supply moderate amounts of d-c power at 180-300 volts.

This instrument is widely used in equipment such as amplifiers, television pulse generators, constant-frequency oscillators.

Other units in the new General Electric line of laboratory measuring instruments include: Visual alignment signal generator, wave meters, wide band oscilloscopes, square wave generators. *Electronics Dept., General Electric, Schenectady, N. Y.*

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ELECTRONIC MEASURING INSTRUMENTS

TYPE AR 300A

(Manufactured to Army-Navy Specification JAN-212E).

Medium power triode for use as audio-frequency amplifier or modulator and radio-frequency oscillator or amplifier at medium frequencies.

A-F Power Amplifier and Modulator—Class B

D-C Plate Voltage	2000 volts
D-C Grid Voltage	-105 volts
Zero-signal D-C Plate Current per tube	40 ma.
Max.-signal D-C Plate Current per tube	300 ma.
Load resistance plate-to-plate	8000 ohms
Power Output (2 tubes)	650 watts

Plate-Modulated R-F Power Amplifier—Class C Telephony

D-C Plate Voltage	1500 volts
D-C Plate Current	300 ma.
D-C Grid Voltage	-200 volts
D-C Grid Current	75 ma. max.
Carrier output for mod. factor of 1.0	300 watts

Makers of high-quality Transmitting and Receiving Tubes since 1926.

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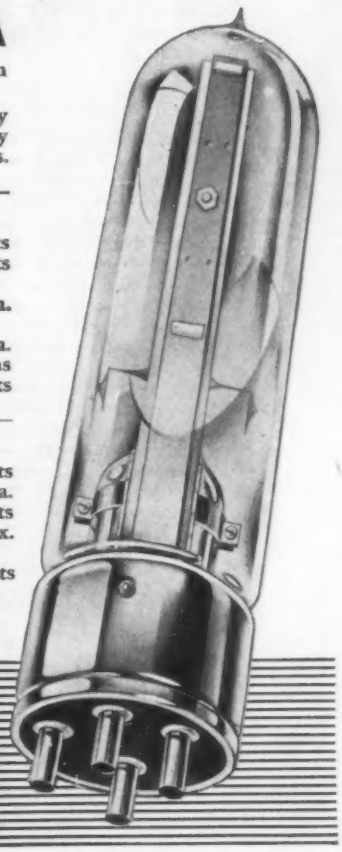

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TORONTO CANADA

TECHNICAL NOTES

Excerpts from New Home Study Lessons Being Prepared under the Direction of the CREI Director of Engineering Texts

Phase Inverter Circuit

Last month, CREI presented the first part of a technical article describing the Phase Inverter Circuit. Part 2, which appears in the September issue of "THE CREI NEWS," gives a typical numerical example of the phase Inverter Circuit and indicates the type of performance that can be expected.

Derivations are then made of the gain and stability of gain of such a stage and it is shown that very good results can be expected. Finally, an analysis of the input admittance is made, as well as remarks on some practical features of the circuit.

Each month "THE CREI NEWS" features such a technical article, in addition to other interesting features concerning The Institute and the industry. We shall be glad to add your name to the mailing list without obligation. Simply write to The Institute at the address below and request the September issue of "THE CREI NEWS" containing the article on the Phase Inverter Circuit.

★ ★ ★

The subject of "Phase Inverter Circuit" is but one of many that are being constantly revised and added to CREI lessons by A. Preisman, Director of Engineering Texts, under the personal supervision of CREI President, E. H. Rietzke. CREI home study courses are of college calibre for the professional engineer and technician who recognizes CREI training as a proven program for personal advancement in the field of Radio-Electronics. Complete details of the home study courses sent on request. . . . *Ask for 36-page booklet.*

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Industrial X-Ray Unit. "Searchray", Model 150, is a self-contained industrial x-ray unit manufactured by North American Philips Co., Inc., for the internal inspection of castings, parts, assemblies, etc., and for locating flaws and defects. This unit is described in folder No. S150 distributed by Walker-Jimieson, Inc., 311 South Western Ave., Chicago 12, Ill.

Adhesive Data. Viscosity, bonding range, and method of application are all contained in a booklet entitled "3-M Adhesive Data" which is designed to serve as a reference book to anyone using adhesives or coating materials, impregnators, spray-on insulators and sound-deadening compounds. Minnesota Mining & Mfg. Co., 411 Piquette Ave., Detroit 2, Mich.

Frequency Meters. Type 21-FX miniature frequency meter, which supersedes Model 21-F, is described in Bulletin VF-43-lb. Meters which operate on 60, 120, and 400 cps are available. These meters are designed to match other 2½ in. panel instruments. J-B-T-Instruments, Inc., 441 Chapel St., New Haven 8, Conn.

Introductory Booklet. "Let Lewyt Do It" is the name of a brochure which illustrates and describes the facilities this company has to offer other manufacturers in the production of mechanical and electrical products. Some of the jobs they do include tool and die, machine work, sheet metal, welding techniques, mechanical and electrical assembly, product finishing, inspection and production engineering. Lewyt Corp., 60 Broadway, Brooklyn 11, N. Y.

Coaxial Transmission Line. Type 83 (⅜ in. diameter), a low loss coaxial transmission line for high or uhf radio frequencies is illustrated and described in Bulletin No. 29, which also contains descriptions of accessories for this line. Andrew Co. 363 East 75th St., Chicago 19, Ill.

Spot Welders. This is the name of a 58-page catalog, No. CE-44W, which shows all types of standard and many special resistance welding machines manufactured in ca-

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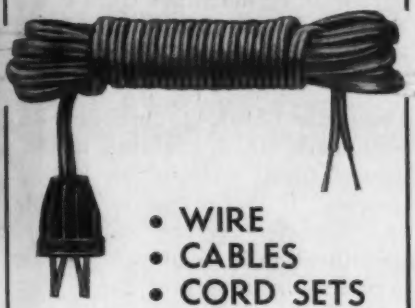

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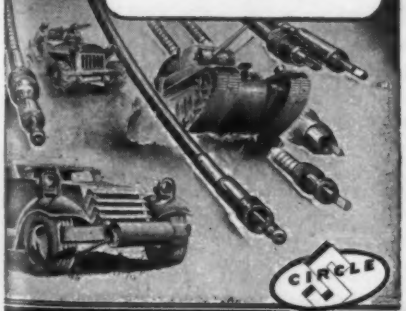

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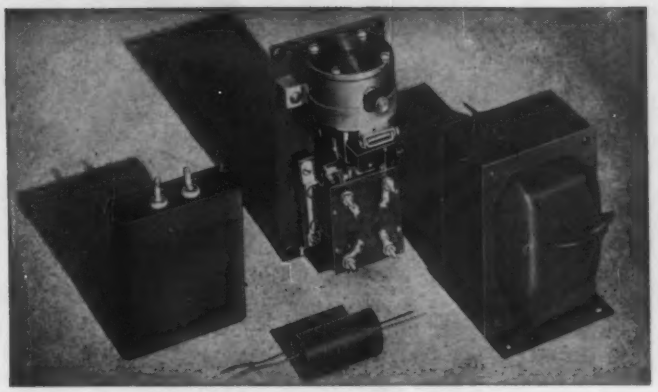

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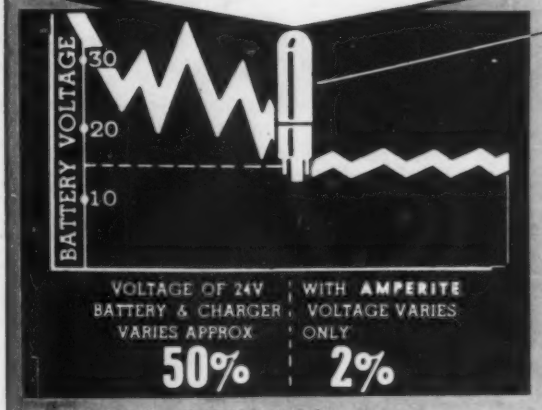

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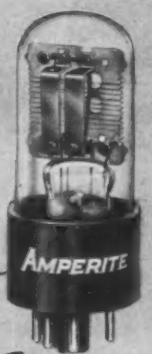

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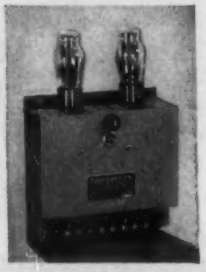

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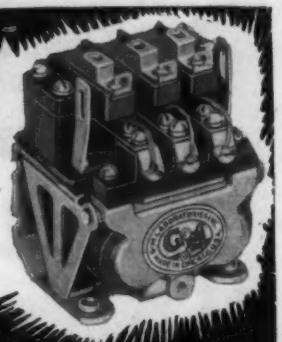

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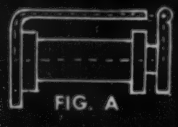

FIG. A

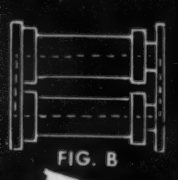

FIG. B

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pacity ranges from 3 kva to heavy duty models up to 500 kva. Another booklet available is called "Light Type Bench Spot Welders" and this booklet features small spot welding machines from ¼ to 3 kva. Eisler Engineering Co., 740 S. 13th St., Newark 3, N. J.

Connector Chart. Type K and RK wall chart, No. 3, contains, in condensed form, material on K connectors. It is for use in schools and factories for the instruction, identification, assembly, ordering, servicing or repair of these connectors and accessories. It is free of charge and is available from Cannon Electrical Development Co., 3209 Humboldt St., Los Angeles, Cal.

Story of Tubes. "It Was a Tube They Wanted" is the name of brochure which briefly tells of the part tubes played in the summer of 1940. It contains illustrations and descriptions of the part this laboratory played in producing tubes. Amperex Electronic Products, 79 Washington St., Brooklyn, N. Y.

Pilot Light Assemblies. "Pilot Light Assemblies for Panel Board and Instrument Signaling" is a 24-page catalog and data book which illustrates and describes pilot light models for a wide range of applications and voltages, including variable intensity and fixed types. Lamps, brackets and accessories are also listed. Gothard Mfg. Co., 1300 N. Ninth St., Springfield, Ill.

Resistance Material. A brief description of this manufacturer's resistance material having negative temperature coefficient is presented in a folder which also contains a graph of typical characteristics of resistance units. Keystone Carbon Co., Inc., St. Marys, Pa.

Colored Brochure. This beautifully colored brochure contains reproductions of various advertisements of this manufacturer's war effort. A very brief description is included of Model SCR-299 mobile radio station. The Hallicrafters Co., Chicago 16, Ill.

NEW BOOKS

Plastics in the Radio Industry

BY E. G. COUZENS AND W. G. WEARMOUTH, *Hulton Press, Ltd., 43 Shoe Lane, London, E. C. 4, 60 pages, price 2/8.*

PUBLISHERS OF *Electronic Engineering* are issuing a series of technical monographs to give radio engineers and students at low cost information that could only be obtained otherwise from a number of books and periodicals. The title is justified largely by the fact that the last of six chapters gives special attention to electrical and dielectric properties of plastics. Tables of comparative properties and graphic charts showing variation of power factor and dielectric constant with temperature are included in this chapter.

The first three chapters give a brief chemical picture of the different types of plastic materials and their manufacture, with the aid of numerous reproduced photographs. These are followed by a chapter devoted to physical properties of plastic products made of different materials and another describing the different methods of fabrication.

Appendices give miscellaneous information such as analyses or names of cements and solvents, how to identify the raw materials by heating tests, and a bibliography of books and articles on plastics.—M.G.V.

• • •

Calculus Refresher for Technical Men

BY A. ALBERT KLAF, *Civil Engineer, Board of Water Supply, City of New York. Whittlesey House, McGraw-Hill Book Co., New York, 1944, 431 pages. Price $3.00.*

DESIGNED FOR THE ENGINEER who has allowed his calculus to get a little rusty, this work serves the purposes of review most effectively by its unusual arrangement as a series of questions with related and full answers. This format likewise helps in reference because each question is set forth in boldface type so a particular point is easy to find.

Subject matter is divided into three sections, one each for differential and integral calculus, and a

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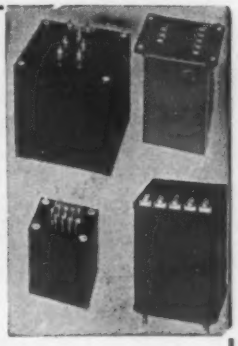

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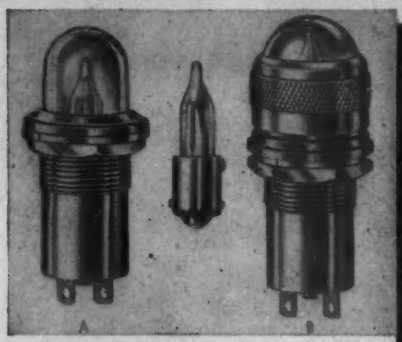

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third presenting applications of calculus to various fields of technology. The integral calculus section includes an introduction to differential equations. All through, the text is illuminated with illustrative examples and problems. Answers are provided in an appendix.

While the volume is primarily set up for use by a technical person with previous training in calculus, the sequence, scope, and depth of the presentation make it equally suitable for use by the student getting his first introduction to the subject.—F.H.

• • •

Radio Waves and the Ionosphere

By T. W. BENNINGTON, *British Broadcasting Corp. Iliffe & Sons Ltd., Dorset House, Stamford St., London, S. E. 1. 85 pages, price 6/-net, 1944.*

MANY WHO WORK with radio or make a hobby of short-wave broadcasting and receiving, but who do not have use for mathematical conceptions of short-wave propagation as the subject is usually presented, will be interested in this little book. Its aim is to explain short-wave communication, and in particular the part that the ionosphere plays in bending radio waves around the earth, in as simple language as possible without any mathematics.

Although the book is not a textbook, it can be recommended as preliminary reading for anyone who is planning to delve deeper and master the mathematics involved.

The six chapters of the book deal with ground waves vs. sky waves, the ionosphere and its characteristics, how the ionosphere is sounded, its variations, long-distance transmission, and disturbances and other abnormalities of the ionosphere.—M.G.V.

• • •

Electronics Today and Tomorrow

By JOHN MILLS, *published by D. Van Nostrand Co., 250 Fourth Ave., New York, N. Y., 1944, 178 pages, price $2.25.*

THE AUTHOR GIVES THE READER the benefit of his more than 30 years of teaching, writing, study and working in the field of electronics. Starting with electrons, he discusses the history of their discovery and in-

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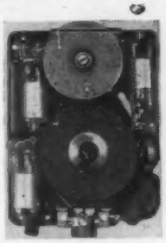

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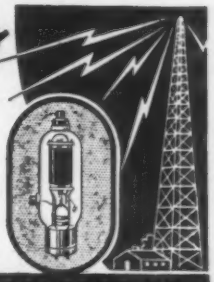

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dicates their characteristics. To illustrate the principles involved he gives a detailed explanation of lightning—both natural and man-made.

Next comes a discussion of various types of electron tubes, how they work and functions which they can perform. Each type of tube is described separately and is introduced with a brief historical sketch of its development. Following this are sections on electron microscopes, the ultra highs or microwaves, ultra-high-frequency generators and cyclotrons.

Mr. Mills' style makes easy reading. All physics and electricity not immediately needed have been ruthlessly omitted. His analogies are appropriate and help immeasurably to explain the highly technical phases of electronics and electronic equipment for the benefit of non-technical readers. However, even electronic technicians should at least enjoy reading the book, and the author's viewpoint and method of handling the material might well stimulate people in the field to greater heights of research, invention and developments.—K.S.P.

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Mechanical and electrical. Graduate or equivalent training. Required for development work in the following branches:

1. Electro-mechanical devices, communication systems. Must be interested in development and familiar with magnetic circuits.
2. Measuring and control instruments. Background should be in electrical engineering, including electronics.

Statement of Availability Required.

P-682, Electronics
330 West 42nd St., New York 18, N. Y.